A Study of the Feasibility of Projects Using Grid Enhancing Technologies and Reconductoring with Advanced Conductors

Submittal to California Independent System Operator Corporation by San Diego Gas and Electric Company in compliance with Cal. Senate Bill 1006

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Contents

1. Introduction

Senate Bill 1006 (SB-1006) [1] requires transmission utilities to conduct two recurring studies by January 1, 2026. A **Grid-Enhancing Technologies (GETs)** study, which must be repeated every two years, and an **Advanced Conductors** study**,** which must be repeated every four years. These studies evaluate opportunities to improve capacity, reliability, and integration of renewable resources while reducing congestion, losses, permitting uncertainties, and wildfire risks.

Both studies must be submitted to the California Independent System Operator Corporation (CAISO) for inclusion in the annual transmission planning processes. San Diego Gas & Electric Company (SDG&E) conducted studies as demonstrated in this report which include:

1. Identification of system constraints that can be mitigated by GETs or advanced conductors
2. Feasibility assessment of selected projects as well as their cost estimates and time to construct

SDG&E utilizes an approach to explore the application of GETs for projects with clear needs, in alignment with existing NERC and CAISO standards. Consequently, the use of GETs in Transmission Planning Process (TPP)'s projects is the focus of this report. In addition, the application of Dynamic Line Ratings has been broadly investigated within the SDG&E network. SDG&E reviewed 3 projects that were previously approved as part of the CAISO 2023-2024 and 2024-2025 Transmission Planning Process (TPP). SDG&E also reviewed 3 project proposals that were submitted as part of the 2025-2026 CAISO TPP. All the assessments in the following sections include information on feasibility, cost, achievable capacity, implementation timelines, and other relevant details.

[1] Bill Text - SB-1006 Electricity: transmission capacity: reconductoring and grid-enhancing technologies.

2. Grid Enhancing Technologies Implementation Assessment

2.1 Topology Optimization

Topology optimization is a software-based solution that dynamically and strategically reconfigures the electrical network's connectivity to improve performance, reliability, and efficiency. It involves modifying how lines and buses are interconnected by implementing or adjusting electrical components such as switches or breakers so that the overall network topology better aligns with operational and planning objectives. SDG&E analyzed its transmission grid and found that the following project could benefit from Topology Optimization software.

2.1.1 Short Circuit Mitigation for Imperial Valley 230 kV Circuit Breakers

In the 2023-2024 TPP, SDG&E submitted a reliability-driven transmission solution to address short circuit duty (SCD) concerns at the Imperial Valley 230 kV substation. By 2035 all 63 kA circuit breakers at the substation will be overstressed due to previously approved TPP projects and the CPUC's Integrated Resource Plan (IRP) base portfolio for that year.

CAISO approved SDG&E' s proposed alternative. The scope of the approved alternative includes:

- Two sets of 10-Ohm current limit reactors (CLRs) in series with 230 kV buses, one on each bus. One CLR will be operated normally open.
- Rearrangement of 230 kV transmission lines; moving TL23043 Imperial Valley – Westside Canal, TL23066 Imperial Valley –Drew, and IID owned S-Line Imperial Valley –Wixom SS to the west buses.

This is the first time that SDG&E plans to use bus series reactors, while keeping one of the bus ties open, to improve system reliability. The cost estimate of this project is ~ $97M with a June 2035 ISD per CAISO approval. This project could be further improved by implementing a Topology Optimization feature that would automatically close the bus tie breaker in the event the other bus tie opens to maintain reliability. Alternatively, two 20-ohm reactors can be installed in parallel and kept normally closed to achieve a similar impact on short-circuit mitigation. This option may cost about the same while reducing complexity from a Grid Operations perspective. Since these two reactors would remain normally closed and always in service, topology optimization schemes may not be necessary in this configuration. Implementing such as a GET can help fulfill items (D), (F), and (G) listed in Appendix A of this report.

Other alternatives listed below were also studied:

- Replace 63 kA with 80 kA circuit breakers: this alternative was not deemed feasible due to constructability issues at the Imperial Valley substation.
- Split the Imperial Valley 230kV buses, add a fourth 500/230 kV transformer and relocate 230 kV transmission lines: this alternative was feasible but not recommended due to concerns on generation curtailment, congestion, and the need of complex operational procedures to mitigate P6 reliability concerns.
- Different rearrangement of 230 kV transmission lines: This alternative included the two CLRs proposed in the selected project but instead of relocating TL23066 Imperial Valley – Drew, TL23045 and TL23046 Imperial Valley -Central LA Rosita II lines 1 and 2 are rearranged to the west buses. The cost estimate for this alternative is ~$112M.

Please refer to Figure 1 for a visual summary of this project's scope.

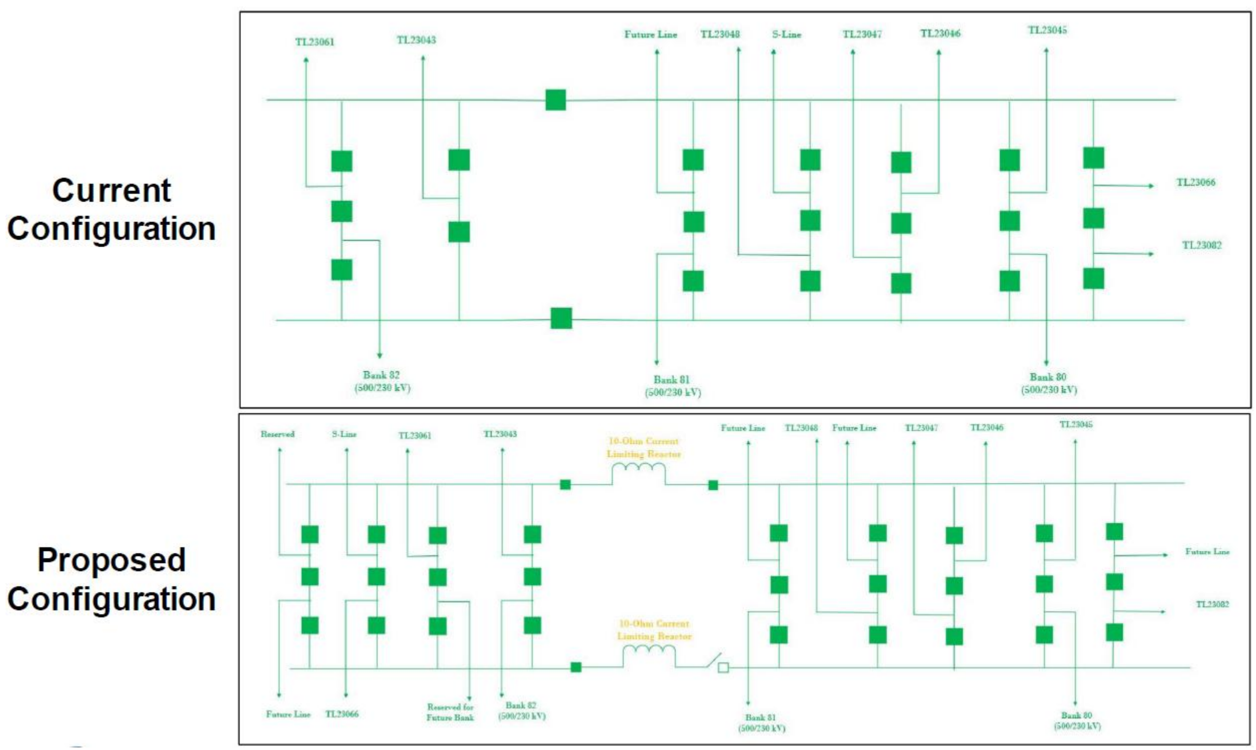

Figure 1. Short Circuit Mitigation for Imperial Valley 230 kV Circuit Breakers

2.2 Advanced Power Flow Controllers

Advanced power controllers are technologies designed to increase the effective capacity and flexibility of the transmission network by influencing how power flows across existing lines. They allow utilities to defer the need to upgrade the transmission system by optimizing the use of current infrastructure. SDG&E assessed whether the application of this technology could be an alternative mitigation for violations observed in its transmission grid. Below please find a description of such projects.

2.2.1 Downtown Reliability Reinforcement Project

In the 2024-2025 TPP, SDG&E submitted a reliability-driven project to mitigate thermal overloads at Old Town 230/69kV Banks. One of the alternatives that SDG&E reviewed with CAISO included GETs. The alternative involved installing two Advanced Power Flow Controllers (APFC) in series with the Old Town 230/69kV banks to mitigate the overloads by dynamically adjusting the effective reactance of the banks. This GETs alternative could achieve items (D) and (G) listed in Appendix A of this report.

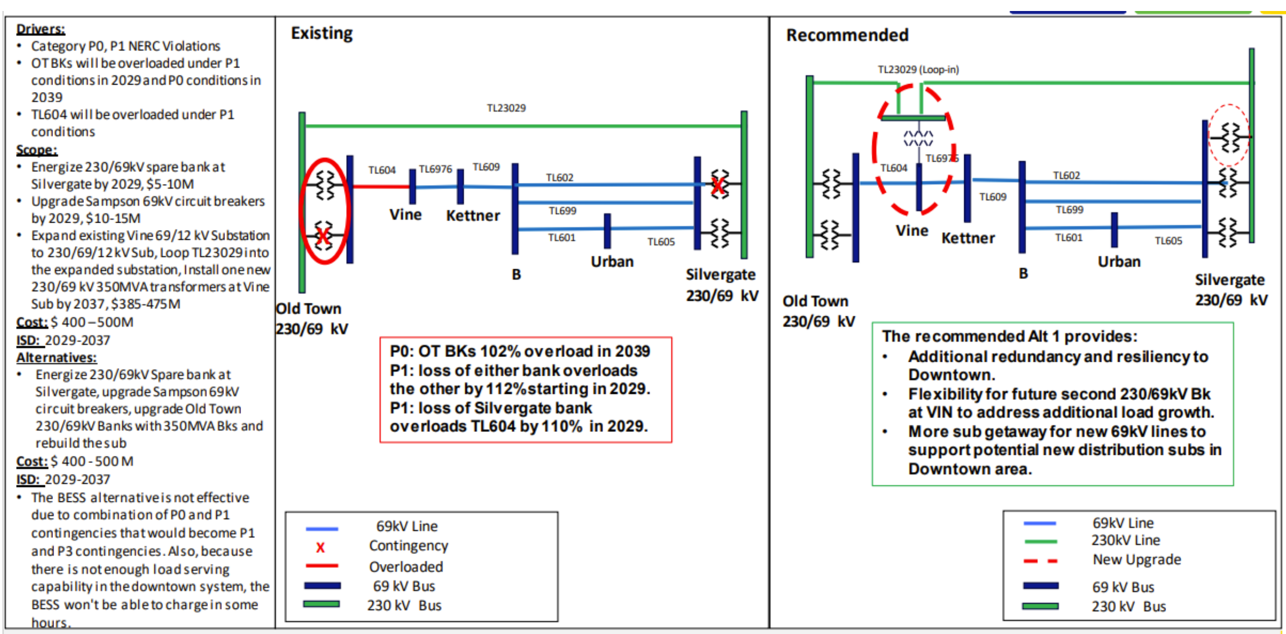

Figure 2.Downtown Reliability Reinforcement Project

Like the alternatives presented in Figure 2, the APFC alternative also requires rebuilding the Old Town substation to GIS. In addition, as load increases beyond 2039, there will be a need to reconductor the following lines:

- TL605 Silvergate – Urban
- TL602 Silvergate – Station B

- TL699 Silvergate – Station B

SDG&E's and CAISO's conclusion is that while this alternative is feasible, it is also costly. The cost is approximately $100M - $120M more than the Old Town rebuilt alternative, with $80M - $90M attributed to the APFC. Compared to the Vine expansion alternative that CAISO approved, this alternative not only had a higher cost but also offered less load-serving capacity and reduced flexibility for accommodating future electrification in the Downtown area.

2.3 Dynamic Line Rating Systems

Dynamic line rating systems (DLR) are technologies that continuously calculate the capacity of transmission lines based on actual environmental and operating conditions—such as temperature, wind speed, and solar radiation—rather than relying on static ratings. In areas with extreme temperature variations, DLRs might unlock additional transmission capacity, reduce congestion, and mitigate certain needs, making better use of infrastructure.

As a result of FERC Order 881, which mandates the use of ambient-adjusted ratings to unlock additional grid capacity in certain conditions, SDG&E is already implementing deviceless DLRs on transmission lines across its system. A deviceless DLR uses weather data and analytical models to adjust transmission line operational ratings without installing sensors on the conductors. It leverages ambient temperature, wind speed, and solar conditions to estimate line capacity, offering a lower-cost and faster alternative to sensor-based DLR. SDG&E already operates one of the most comprehensive networks of weather stations and anemometers in the country, making the implementation of deviceless DLRs both practical and efficient. This approach is scalable, maintainable, and can be deployed across a transmission system. Deviceless DLRs provide system-wide ratings, are easier to validate through statistical studies, and align with the goals of regulatory reforms. Validation is achieved through LiDAR capture and transmission modeling, ensuring comprehensive coverage and reliability. SDG&E anticipates completing the implementation of ambient-adjusted operational ratings using deviceless DLRs by the end of 2027. SDG&E's implementation of DLRs will satisfy requirements A to G of section (c) (2) of SB-1006.

2.4 Reconductoring with Advanced Conductors

Reconductoring with advanced conductors involves replacing existing transmission line wires with high-capacity, low-sag conductors that can carry significantly more electricity over the same structures. This approach allows utilities to increase transmission capacity without building some new corridors, helping meet long-term reliability and renewable integration goals. Below, SDG&E shows the assessments it has performed with advanced conductors.

2.4.1 Upgrade TL13820 Sycamore-Chicarita 138 kV

To address the Sycamore Area constraint identified in the base and sensitivity portfolios, during the 2022-2023 TPP, the ISO recommended the Upgrade TL13820 Sycamore-Chicarita 138 kV project.

The scope of the project is as follows:

- Reconductor Sycamore- Chicarita 138 kV line to 250 MVA
- The estimated project cost is $60 million and is expected to be in service in 2032.

To address the reconductor' s high rating requirement, SDG&E chose to implement the Aluminum Conductor Composite Core (ACCC) which is a type of advanced conductor. This modern, high capacity, overhead conductor is designed to address the limitations of traditional conductors. ACCC utilizes a composite core made from carbon and glass fibers embedded in a thermoset resin. This advanced core material offers exceptional tensile strength while exhibiting very low thermal expansion, which significantly reduces conductor sag at elevated temperatures. The diameter of the carbon core is typically smaller than a traditional steel core used in ACSR conductor allowing more aluminum conductors within the same diameter. This allows it to replace existing conductors and potentially minimize structure replacements based on conductor sag and structure loading.

The advanced conductor in this project can provide items (A), (B), (C) and (F) listed in Appendix A of this report.

2.4.2 69kV Line Reconductor Projects

To address the 69kV constraints identified during the 2025-2026 TPP, SDG&E recommended reconductoring several 69kV lines within the territory.

These reconductor projects were also screened for applicability of other GETs discussed in this report, however, Dynamic line rating systems, advanced power flow control systems, and topology optimization software were deemed to either not be applicable due to the to the radial nature of the congested corridor or to not provide enough rating increase during hot summer periods.

In accordance with items (A), (B), (C) and (F) listed in Appendix A of this report, and to address the high rating requirement of the reconductor jobs, SDG&E assessed the implementation of ACCC as an alternative for these projects.

69kV reconductors proposed by SDG&E often lie within an aged wood-pole infrastructure where structural change out (full-rebuild) is typically required to provide the necessary structural support and integrity for any larger or higher design tension conductor installed. In addition, transmission lines were designed to the standards in effect at the time of construction including known local conditions. For older transmission lines, they would have been designed to existing GO95 structural requirements, however, meteorological data has generated new known local wind conditions that must be accounted for at install of new conductor that may overload existing structures requiring full replacement. A full detailed structural analysis of each pole (including steel) within a 69kV transmission line would need to be conducted to determine if ACCC would be a feasible option and what structures would require replacement.

Transitions from SDG&E's standard ACSS/ACSR to ACCC conductors on a per span basis create imbalances in structural loading within a linear oriented transmission line, thus creating concerns in wood pole loading integrity and maintaining proper conductor clearances on a basis of limited engineering at the cost estimate phase.

It's also important to note that thermal rating of a conductor is mainly dictated by conductor ground and phase clearance constraints (GO 95) at the conductors maximum operating temperature. In most cases, to achieve a higher MVA rating on a line requires a larger conductor. To achieve a similar rating on a similar or smaller conductor would require higher conductor stringing tensions which in turn increases the structural loading on the poles and hardware thus triggering pole replacements. This rationale can be applied in general to the TL623C, TL600B, TL690B and TL697 proposed reconductors described below.

The upper bound of the cost estimate ranges below corresponds to scenarios where a full rebuild utilizing standard conductor types are used. The lower bound of the ranges assumes where ACCC conductors can be utilized without structure replacements for the sections of the line that appear possible from a preliminary review. However, the cost of the ACCC option may increase depending on the existing structure capacity and its compliance with current standards.

2.4.2.1 *Reconductor TL600B Clairemont-Clairemont Tap 69 kV*

To address the Clairemont Area constraint identified, SDG&E recommended the TL600B Clairemont-Clairemont Tap 69 kV Reconductor project.

The scope of the project is as follows:

- Reconductor Clairemont-Clairemont Tap 69 kV line to achieve 85 MVA rating
- The estimated project cost is within the range of $4-8 million and is expected to be in service in 2035.

This project mitigates P1 violations in the Clairemont area, while providing support for area load growth.

2.4.2.2 *Reconductor TL690B Oceanside-Oceanside Tap 69 kV & TL697 Oceanside-San Luis Rey 69 kV*

To address the Oceanside Area constraint identified, SDG&E recommended the TL690B Oceanside- Oceanside Tap 69 kV & TL697 Oceanside-San Luis Rey 69 kV Reconductor project as an alternative mitigation.

The scope of the project is as follows:

- Reconductor ~1.6 miles of TL690B (Oceanside-Oceanside Tap) and ~6 miles of TL697 (Oceanside-San Luis Rey) to achieve136 MVA rating
- The estimated project cost is within the range of $88-100 million and is expected to be in service in 2031.

2.4.2.3 *Reconductor TL623C Otay Tap-San Ysidro 69 kV*

To address the Border and Imperial Beach Area constraint identified, SDG&E recommended the TL623C Otay Tap- San Ysidro 69 kV Reconductor project as an alternative mitigation.

The scope of the project is as follows:

- Reconductor Otay Tap- San Ysidro 69 kV line to achieve 136 MVA rating
  The estimated project cost is within the range of $3-6 million and is expected to be in service in 2032.

3. Conclusion

SDG&E remains committed to fulfilling the requirements of SB-1006 by exploring and implementing Grid Enhancing Technologies (GETs) as practical solutions for achieving the statute's objectives. As part of the TPP and in collaboration with CAISO, SDG&E has identified and proposed a portfolio of projects designed to improve system reliability and efficiency. The alternatives of these projects were reviewed for the deployment of advanced conductors, topology optimization strategies, and advanced power flow controllers. Each proposed project is supported by cost estimates, detailed construction schedules, and feasibility assessments to ensure practical implementation.

In addition, SDG&E is implementing deviceless DLR across its service territory which it expects will benefit the operation of the system.

This effort reflects SDG&E's ongoing commitment to meeting the bi-annual study requirements outlined in SB-1006, working closely with CAISO to deliver cost-effective, constructible, and timely solutions that enhance grid reliability. The next scheduled SB-1006 assessment will occur in 2028, continuing the cycle of proactive planning and collaboration.

4. Appendix A: Senate Bill 1006 Description and Requirements

4.1.1 Implementation of Grid-Enhancing Technologies (GETs)

Per (c) (1) of SB-1006, On or before January 1, 2026, and every two years thereafter, each transmission utility shall prepare a study of the feasibility of projects using grid-enhancing technologies (GETs). The transmission utility shall provide information on feasibility, cost, rating, implementation time, and any other necessary information to the Independent System Operator at the same time as any other projects proposed to be part of the Independent System Operator's annual transmission planning process. The transmission utility shall request the Independent System Operator to review the results of the study as part of its annual transmission planning process for economic, reliability, and policy goals, and shall request the Independent System Operator to include grid-enhancing technologies in all transmission planning studies and analyses.

The study shall be designed to identify projects using grid-enhancing technologies that can achieve one or more of the following:

A. Increase transmission capacity.
B. Reduce transmission system congestion.
C. Reduce curtailment of renewable and zero-carbon resources.
D. Increase reliability.
E. Reduce the risk of igniting wildfire, by means of investments that are consistent with the transmission utility's approved wildfire mitigation plan.
F. Increase capacity to connect new renewable energy and zero-carbon resources.
G. Increase flexibility to reduce risks surrounding technology and permitting uncertainties in statewide electrical system planning and improve optionality for load-serving entities.

4.1.2 Implementation of Advanced Conductors

Per (d) of SB-1006, On or before January 1, 2026, and at least every four years thereafter, each transmission utility shall prepare a study of which of its transmission lines can be reconductored with advanced conductors. The transmission utility shall provide information on feasibility, cost, rating, implementation time, and any other necessary information to the Independent System Operator at the same time as any other projects proposed to be part of the Independent System Operator's annual transmission planning process. Each transmission utility shall request that the Independent System Operator review the results of the study as part of its annual transmission planning process for economic, reliability, and policy goals, and shall request the Independent System Operator to include reconductoring with advanced technologies in all transmission planning studies and analyses.

The study shall identify electrical lines where reconductoring with advanced conductors can achieve one or more of the following:

A. Significantly increase transmission capacity.
B. Reduce transmission system congestion.
C. Reduce curtailment of renewable and zero-carbon resources.
D. Increase reliability.
E. Reduce the risk of igniting wildfire, where the investment is consistent with the transmission utility's approved wildfire mitigation plan.
F. Increase capacity to connect new renewable energy and zero-carbon resources.
G. Reduce line losses.
H. Increase the ability to quickly energize new customers or serve increased customer load.
I. Increase flexibility to reduce risks surrounding technology and permitting uncertainties and improve optionality.