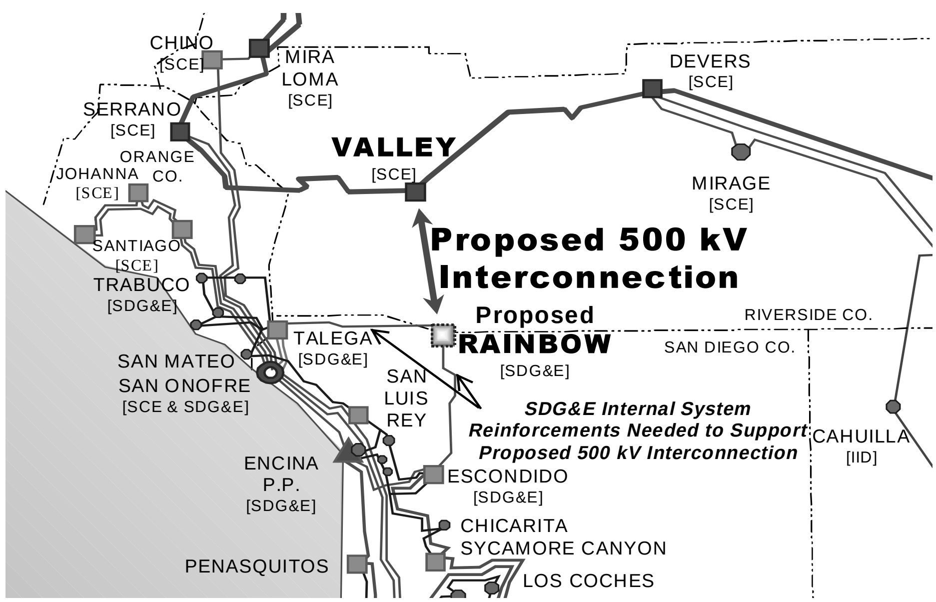
Attachment A

# Valley - Rainbow Interconnection Project
# Feasibility Study Report

***A Joint Study Effort of San Diego Gas & Electric (SDG&E)***
***and Southern California Edison (SCE)***
***in Cooperation with the***
***California Independent System Operator (Cal-ISO)***

***Intended to Fulfill the Requirements of a***
***WSCC Comprehensive Progress Report***




## FINAL DRAFT

**May 12, 2000**

## TABLE OF CONTENTS

# TABLES



# FIGURES

## EXECUTIVE SUMMARY

The 500 kV Valley – Rainbow Interconnection Project (the "Project") has been proposed by San Diego Gas & Electric (SDG&E), the "Project Sponsor[1]", as a part of its 1999 annual transmission assessment, conducted in cooperation with the California Independent System Operator (Cal-ISO) and interested stakeholders. Since the Project is a proposed interconnection between SDG&E and Southern California Edison (SCE), SCE has worked closely with SDG&E in pursuing joint studies of this proposal. Portions of this study were performed on behalf of SDG&E by General Electric's Power System Consulting Group.

This report is the result of these studies and is intended to demonstrate the feasibility of the proposal. The report is also intended to address all the issues applicable to a "Comprehensive Progress Report" as defined by the Western Systems Coordinating Council (WSCC), so as to meet one of the requirements of Phase 1 of transmission path rating process. This path rating process is defined in WSCC's March 1996 *"Procedures for Regional Planning Project Review and Rating Transmission Facilities"* (the WSCC "rating procedures").

The studies have compared the Valley – Rainbow proposal with three other alternative 500 kV proposals:

- Devers – Rainbow;
- Mira Loma – Rainbow; or
- A second Southwest Powerlink (SWPL) from Palo Verde to Miguel.

The studies have concluded that the Valley – Rainbow Interconnection is the preferred alternative, for the following reasons:

- shortest line mileage and most cost effective;
- presents least amount of construction difficulties;
- more realistic to achieve in the proposed time frame; and
- comparable performance to other alternatives.

The recommended transmission Plan of Service is as follows:

- a 500 kV line from SCE's Valley Substation to a new SDG&E Rainbow[2] Substation (approximately 40 miles in length);
- a loop-in of SDG&E's Talega - Escondido 230 kV Line into Rainbow to form Talega - Rainbow and Rainbow - Escondido 230 kV Lines, and bundling those two lines;
- addition of a second bundled Talega - Rainbow and a second bundled Rainbow - Escondido 230 kV Line;

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[1] It is yet to be determined whether SDG&E will be the sole Project Sponsor, or others would become involved in joint participation.

[2] Wherever the Rainbow Substation is referenced, the nearby Pala site would also apply. SDG&E evaluation of the two alternative sites is pending, but the final site selection will have no significant impact on the study results.

- 500/230 kV transforming capability at Rainbow Substation (rated at least 1120 MVA);
- one or two (depending on capability) phase-shifting transformer [or alternative Flexible AC Transmission System (FACTS) device];
- a total of at least 350 MVAR of dynamic reactive power support and 990 MVAR of static power support; and
- some local reinforcements in the Escondido 69 kV area and elsewhere[3], which will be addressed during SDG&E's annual transmission assessment.

No reinforcement needs were identified in the SCE system other than those associated with terminating the line in SCE's Valley Substation.

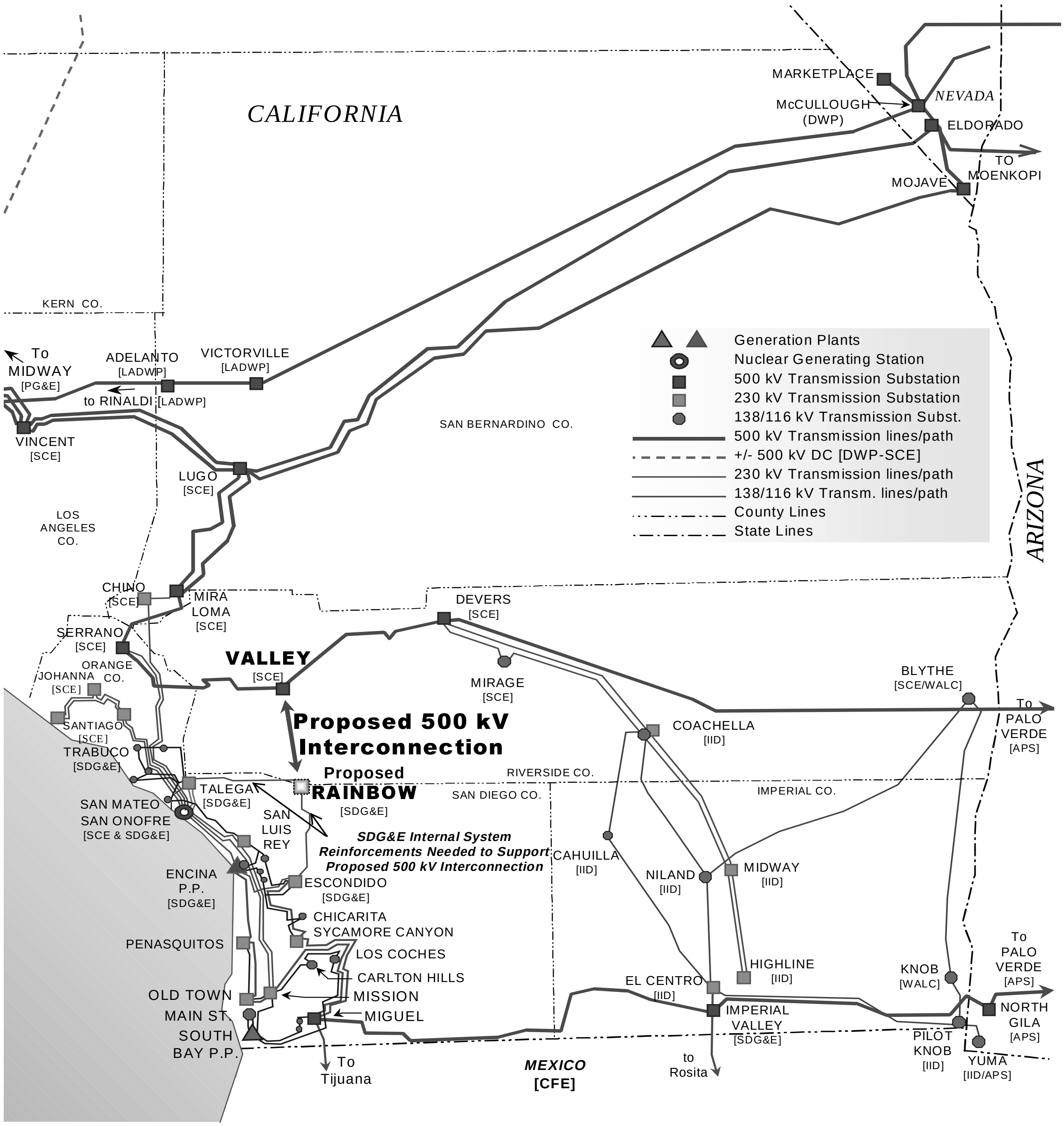
Based on the study results, the Project is capable of a "Planned Rating" (non-simultaneous maximum rating) of 1000 MW. The Project is anticipated to increase SDG&E's system import capability to about 3600 MW.

Figure 1, the "Valley – Rainbow Interconnection Project Overview", provides a geographic diagram that indicates the general location of the proposed project and the existing transmission system in the area.

The Valley-Rainbow alternative is expected to integrate well with future bulk power system expansion concepts as envisioned by SDG&E and the ISO, but no modeling of such long-term expansion scenarios was done in the current study due to the absence of credible resource planning assumptions beyond 2004.

[3] Certain upgrades identified in these studies may be needed for the future SDG&E transmission expansion, but are not directly the result of the Valley – Rainbow proposal (or alternative). Such upgrades, that may be needed with or without the proposed project include a new 392 MVA 230/138 kV TCUL transformer for Sycamore Canyon Substation, a loop-in of the Chicarita – Carlton Hills Tap 138 kV Line into Sycamore Canyon Substation, bundle both San Luis Rey – Mission 230 kV Lines with 2-1033 kCMIL ACSR, and develop a continuous emergency rating for the Encina – Peñasquitos 230 kV Line. These projects will be evaluated as a part of SDG&E's annual transmission expansion stakeholder process.

# Valley - Rainbow Interconnection Project Overview



## INTRODUCTION

The "Valley-Rainbow Interconnection Project" (the "Project") has been proposed by San Diego Gas & Electric (SDG&E) to address the need to meet the California Independent System Operator (ISO) Grid Planning Criteria as its load continues to grow. By 2004, the SDG&E system needs major reinforcement to comply with the ISO Grid Planning Criteria for:

- N-1 Single Line outage;
- G-1 Single Generator outage; and
- G-1 / N-1 Generator outage, system adjusted, followed by a Line outage.

Studies have been performed jointly with Southern California Edison (SCE), in cooperation with the California ISO. The primary need for the Project is to meet the increasing load demand in the SDG&E service territory, including San Diego County and Southern Orange County. This study has been performed to conform with the WSCC Procedures for Regional Planning Project Review and Rating Transmission Facilities, ISO Grid Planning Criteria, WSCC Reliability Criteria, WSCC Voltage Stability Criteria, and NERC Planning Standards as follows:

- WSCC "Procedures for Regional Planning Project Review and Rating Transmission Facilities" (March 1996 version)
- Cal-ISO Grid Planning Criteria (January 1999 version);
- WSCC "Reliability Criteria For Transmission System Planning" (March 1999);
- WSCC "Voltage Stability Criteria, Undervoltage Load Shedding Strategy, and Reactive Power Reserve Monitoring Methodology"; and
- NERC Planning Standards (September 1997).

A notification letter was sent to all PCC and TSS members of WSCC on November 19, 1999, advising them that SDG&E intended to begin project studies within Phase 1 of the WSCC rating procedures. Also, an "Initial Progress Report" was issued on March 7, 2000 to all PCC and TSS members of WSCC to further inform them of progress up to that point.

For efficiency and expediency, this report documents the joint feasibility studies performed by SDG&E and SCE, and concurrently serves as a WSCC Comprehensive Progress Report. As such, the report demonstrates conformance with the WSCC Reliability Criteria. In conformance with the requirements of a WSCC Comprehensive Progress Report, this report contains information intended to meet the following eight WSCC requirements.

1. "A brief description of the project, including a statement on the status of design."

2. "A one-line or geographic diagram of the project."

3. "A block diagram, transfer functions, equations and complete definition of the model or models needed to study the new facility using power flow and transient

stability computer programs. This information is not required if the necessary model or models are already available in the WSCC power flow and stability programs."

4. "A statement describing the transfer capability associated with the project, the impact on other systems, and compliance with the Reliability Criteria."

5. "A description of the interconnected system conditions on which the proposed transfer capability rating is based."

6. "A representative list of power flow and stability cases run that demonstrate compliance with [the] Reliability Criteria."

7. "Representative power flow cases and stability plots that demonstrate compliance with the Reliability Criteria."

8. "A project milestone schedule that covers the period through initial operation of the project. This schedule should be sufficiently detailed to allow for monitoring by the TSS members."

This report contains findings in regard to the non-simultaneous transfer limitations associated with the Project, and certain limited information regarding any known simultaneous transfer limitations known to date. If a decision is made to proceed with the Project, then simultaneous transfer limitations will be addressed in depth in Phase 2 of the WSCC rating process, to any reasonable extent requested by other WSCC member systems.

For consistency with the ISO regional studies, all cases used in the Valley – Rainbow study were based in the Heavy Summer case developed by the Cal-ISO for the 2004 Composite Study, with the SDG&E and SCE areas represented to reflect their 1999 annual assessment studies for the year 2004. The cases developed for the Valley – Rainbow study are also being used in the SONGS Phase II study being performed concurrently by Cal-ISO, SDG&E and SCE.

Base case preparation and thermal analysis were performed jointly by SDG&E and SCE. GE Power System Energy Consulting was contracted to perform a portion of the Valley-Rainbow feasibility studies. The scope of work and objective of the GE consultants was to perform voltage stability and transient stability analysis to evaluate the impact of the four interconnection alternatives on the performance of the SDG&E and SCE systems.

### *Rainbow vs. Pala Site Alternative*

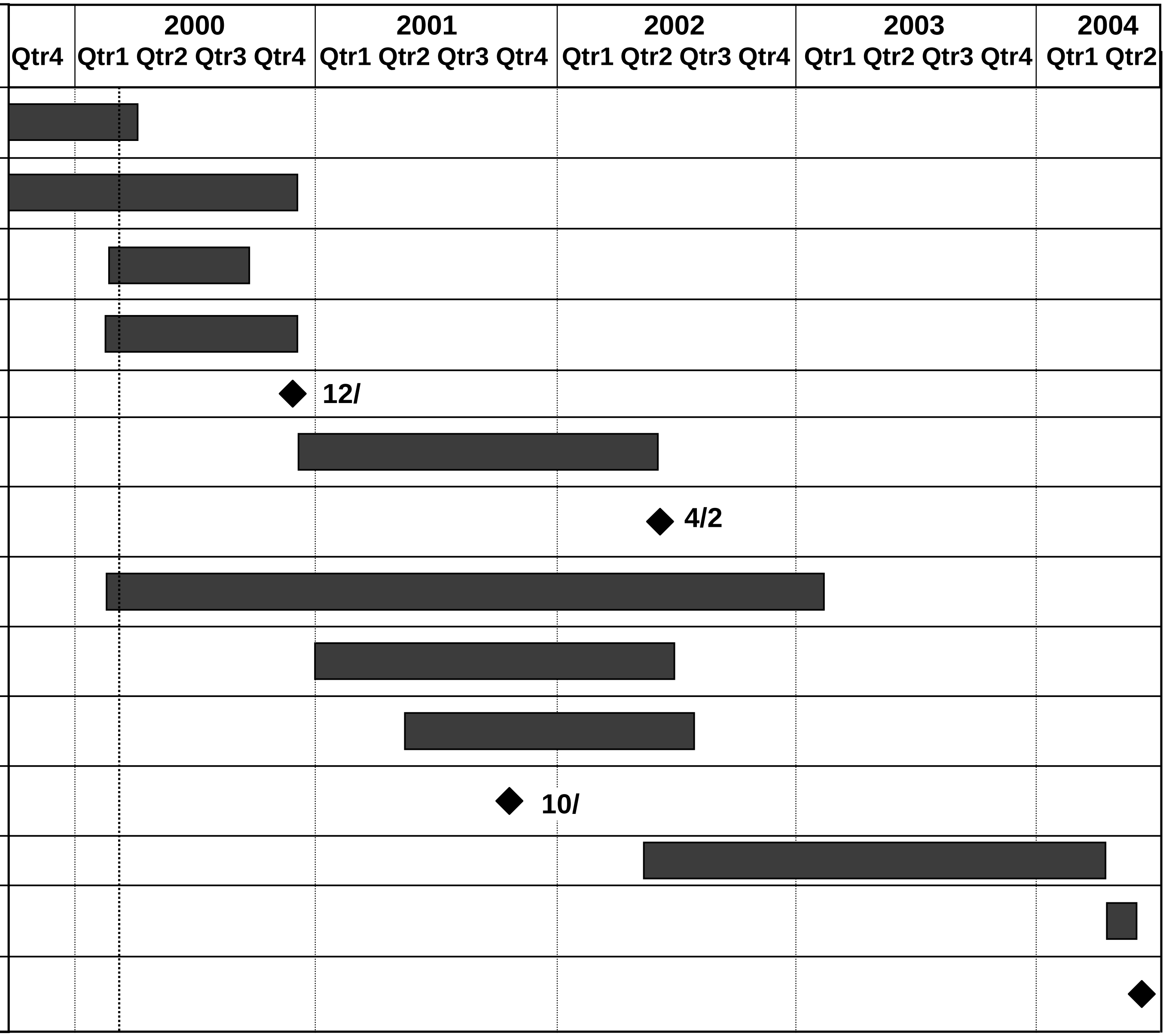
In addition to the Rainbow site, SDG&E is considering the use of an alternative substation site at Pala located about 5 miles further to the south along the Talega - Escondido 230 kV line Right-of-Way (ROW). SDG&E intends to evaluate the potential advantages of developing the Pala site for this project as compared to the Rainbow site. Because of the close proximity of the Pala site to Rainbow, the study results are not expected to change if a final decision is made to use the Pala site instead of Rainbow.

If Pala is selected, the 500 kV line will run for approximately 5 miles south beyond Rainbow in parallel with the Talega-Pala 230 kV lines. A powerflow was run for the possible N-3 common corridor outage scenario (two 230kV lines and the 500kV line) and no loading violations were found.

Wherever this report references the “Valley – Rainbow” 500 kV line, it includes the possibility of a “Valley – Pala” 500 kV line being selected as an alternative. The same possibility would also apply to the Devers or Mira Loma alternatives as well.

## Valley - Rainbow 500 kV Project Schedule

| ID | Task Name | Start | Finish |
|---|---|---|---|
| 1 | Feasibility Study | 10/6/99 | 3/31/00 |
| 2 | Preliminary Eng/Design | 10/6/99 | 12/4/00 |
| 3 | ISO Approval | 2/25/00 | 9/29/00 |
| 4 | PEA/NEPA Preparation | 2/11/00 | 12/4/00 |
| 5 | File CPCN | 12/4/00 | 12/4/00 |
| 6 | Licensing (CPUC) | 12/4/00 | 4/26/02 |
| 7 | CPUC Approval | 4/26/02 | 4/26/02 |
| 8 | Right-of-Way Acquisition | 3/1/00 | 2/6/03 |
| 9 | Detailed Eng/ Design | 1/1/01 | 7/2/02 |
| 10 | Material Procurement | 5/1/01 | 7/30/02 |
| 11 | Order Major Equipment | 10/1/01 | 10/1/01 |
| 12 | Construction | 5/1/02 | 4/5/04 |
| 13 | Testing / Energize | 4/6/04 | 5/31/04 |
| 14 | Commercial Operation | 6/1/04 | 6/1/04 |



## CONCLUSIONS

The Valley – Rainbow alternative provides significant reinforcement to ensure meeting reliability requirements in the SDG&E system without adverse impact on neighboring utilities or elsewhere in the WSCC interconnected system. There is no significant difference in technical performance among the different alternatives terminating in the Rainbow/Pala area. Technical results indicate that comparable facilities additions will be needed at Rainbow Substation and internal to the SDG&E system with either the Valley – Rainbow, the Devers – Rainbow, or the Mira Loma – Rainbow 500 kV alternatives. There is a small difference in shunt capacitor requirements (less than 100 MVARs), and phase-shifter control angle requirements, which are considered minor for alternative selection purposes. However, due to the increased corridor length, there would be additional costs, licensing activities and construction difficulties associated with either the Mira Loma – Rainbow or Devers - Rainbow alternatives. Therefore, the Valley - Rainbow alternative is the preferred northern interconnection option. The second SWPL alternative could potentially offer some electrical performance advantages, but it has significant drawbacks of far greater distance, cost, licensing and construction time requirements, and could subject the system to the risk of a very severe N-2 common corridor contingency (i.e., SWPL#1 and #2). Therefore, Valley - Rainbow remains the best alternative, and has the following advantages as compared with the other alternatives:

1. **Shortest line length**
   The Rainbow – Valley alternative has the shortest distance (about 40 miles) as compared with the other alternatives being considered. All other alternatives are at least twice the length of the Rainbow Valley alternative. In particular, the second SWPL alternative is about 240 miles longer than the preferred alternative.

2. **Most reliable**
   Since the Rainbow – Valley alternative is relatively a short line, it has the lowest exposure to outages. There are no other 500 kV transmission lines on the proposed corridor(s), which minimizes the risk of any simultaneous 500 kV line outages.

3. **Lowest cost**
   The Valley – Rainbow is the shortest alternative in line length and has the lowest projected cost as compared with the other alternatives

4. **Least construction difficulties**
   Multiple route options have been identified for the Rainbow – Valley alternative, and the line is relatively short, which minimizes the chance of construction difficulties compared to the other alternatives.

5. **Highest likelihood for meeting a 2004 in-service date.**
   Due to its short length and an existing right-of-way, this alternative has the highest probability for meeting the proposed 2004 in-service date.

6. **Compatible with the long-term planning concepts**
   The Valley – Rainbow alternative is compatible with long-term planning concepts currently being considered for reinforcement of the region, including grid expansion concepts to mitigate the absence of the SONGS units

The Valley – Rainbow Project allows SDG&E to import more power in 2004 and beyond in a cost-effective, reliable manner. All practical 230 kV alternatives have been exhausted (either already constructed or planned prior to 2004). Without the Valley - Rainbow Project, the SDG&E system would need many lower voltage "Band-Aid" type upgrades in 2004 and beyond, which are not efficient or cost-effective, or would require load shedding contrary to the ISO grid planning criteria and standards. Accordingly, serious consideration of lower-voltage alternatives was rejected at the outset of the study for reasons that continue to be described below.

The Valley - Rainbow Project is especially beneficial during SWPL outage conditions. Without the Valley - Rainbow project, an outage of SWPL would cause the power which was flowing on SWPL before the outage to flow on South-of-SONGS lines. Upgrading of many 230 kV, 138 kV and 69 kV lines would be required in the South-of-SONGS area and elsewhere in the SDG&E system.

The following 230 kV projects were already proposed in the SDG&E 1999 Grid Planning Assessment.

- Install a new 230/69 kV transformer at San Luis Rey Substation – 2000
- Bundle San Onofre – San Luis Rey 230 kV Line – 2000
- Install a new 230/69 kV transformer at Sycamore Canyon - 2001
- Install a new 230/69 kV transformer at Escondido Substation – 2001
- Expand 230 kV Capability at San Luis Rey Substation – 2002
- Bundle SONGS – Talega #1&2 230 kV lines - 2004 (currently under review)
- Add reactive power support

Additional import-related projects that may be proposed based on the Year 2000 Grid Planning Assessment include the following.

- Bundle San Luis Rey – Mission #1 & 2 230 kV lines – 2002
- Install a new 230/138 kV transformer at Sycamore Canyon and build a 138 kV switchyard – 2004
- Add additional reactive power support needed for 2001-2003

With the above projects, the ability to efficiently expand SDG&E's internal system upgrades will be exhausted. Therefore, further import increases beyond 2003 will require new interconnections from SDG&E to the ISO Controlled grid. Since no 230 kV source exists at SCE's Valley Substation, a 230 kV option would require construction of a 500/230 kV Substation at Valley or connection to SCE's Mira Loma or Devers 230 kV Substation at costs similar to those determined for the Mira Loma and Devers 500 kV options. In order to integrate with the long-term expansion needs, SDG&E would still have to build the line using 500 kV design, and initially operate it at 230 kV. A 230 kV plan would also result in significantly greater reactive power requirements and increased system losses.

Lastly, the Valley - Rainbow Project provides a third, independent, major point of interconnection for the SDG&E system. Upgrading existing 230 kV lines would not provide the same level of reliability as the Valley – Rainbow Project. Even if the SONGS 230 kV corridor could be upgraded to increase the SDG&E import to 3600 MW, only two major points of interconnection would be available to SDG&E (at SONGS and Miguel). The Valley – Rainbow Project provides a third point of interconnection at Rainbow, which is geographically removed from Miguel and SONGS. In the absence of the Valley – Rainbow Project, if SWPL were to be lost due to an outage, then the SDG&E system would only have one major point of interconnection at SONGS.

**Table 2 summarizes key factors used to compare the different alternatives.**

Table 2

# Key Factors Used To Compare Alternatives

| | **Valley-Rainbow/Pala** | **Devers-Rainbow/Pala** | **Mira Loma-Rainbow/Pala** | **Second SWPL** |
|---|---|---|---|---|
| Simultaneous Import Level into SDG&E | 3600 MW | 3600 MW | 3600 MW | 3600 MW |
| Potential Non-Simultaneous rating in WSCC | 1000 MW | 1000 MW | 1000 MW | ~1000 MW |
| Simultaneous concerns | WSCC Phase II Study | WSCC Phase II Study | WSCC Phase II Study | WSCC Phase II Study |
| Reactive power support requirements for 3600 MW of import into SDG&E | 1000-1350 MVAR | 1000-1350 MVAR | 1000-1350 MVAR | 1000-1350 MVAR |
| Phase Shifting Transformer angle to hold flow at 1000 MW non-simultaneous rating | 27.120 | 33.050 | 27.890 | N/A |
| Pre-project to post-project delta (change in MW flow) in key 500 kV lines | | | | |
| -Palo Verde - Devers 500 kV line | 342 | 434 | 231 | 52 |
| -Serrano - Valley 500 kV line | 609 | 383 | -129 | -25 |
| -Devers - Valley 500 kV line | 405 | -381 | 129 | -45 |
| - Mira Loma - Serrano 500 kV line | 262 | 143 | -267 | 51 |
| -South of Lugo 500 kV line | 458 | 384 | 592 | 188 |
| Incremental system losses (post-project vs. pre-project) | | | | |
| -SDG&E real losses | 28.32 | 28.87 | 28.62 | 31.34 |
| -SDG&E reactive losses | 409.07 | 413.01 | 414.81 | 578.02 |
| -SCE real losses | 57.28 | 62.23 | 48.13 | 17.68 |
| -SCE reactive losses | 1029.04 | 938.58 | 724.53 | 368.67 |
| Preliminary short circuit performance | @Valley 500/115 | @ Devers 500/230 | @Mira Loma 500/230 | N/A |
| - actual value (* denotes over 80% rating) | 11.8/4 GVA | 11.1/9.1*GVA | 26.3/23.1*GVA | N/A |
| - ratings | 35/8 GVA | 35/10 GVA | 35/25 GVA | N/A |
| - (pre-project - post-project) | 1.6/.8 GVA | 1.3/.3 GVA | 1.0/.3GVA | N/A |
| Mileage (approximately) | 40 mi. | 95 mi. | 113 mi. | 280 mi. |
| Construction difficulties | low/medium | medium/high | high | very high |
| Timing | 2004 | >2004 | >2004 | >2004 |
| Preliminary Ranking (based on mileage cost) | 1 | 2 or 3 (tie) | 2 or 3 (tie) | 4 |

* SCE Circuit breakers with loading greater than 80% require an engineering evaluation to determine the breaker-specific allowable overstressing capability.

The following facility additions would be required for the alternatives that terminate in the Rainbow/Pala area[4].

- Construct a 500 kV line from the existing Valley 500 kV (approximately 40 miles), Devers 500 kV (approximately 93 miles) or Mira Loma 500 kV (approximately 113 miles) to the new Rainbow or Pala 500 kV site (a bundled 2156 ACSR conductor is presently assumed, but further analysis during the design phase may optimize the conductor type and size).

- Develop a 500/230 kV substation[5] at either the Rainbow or Pala site with an ultimate design as shown in Figure 2.

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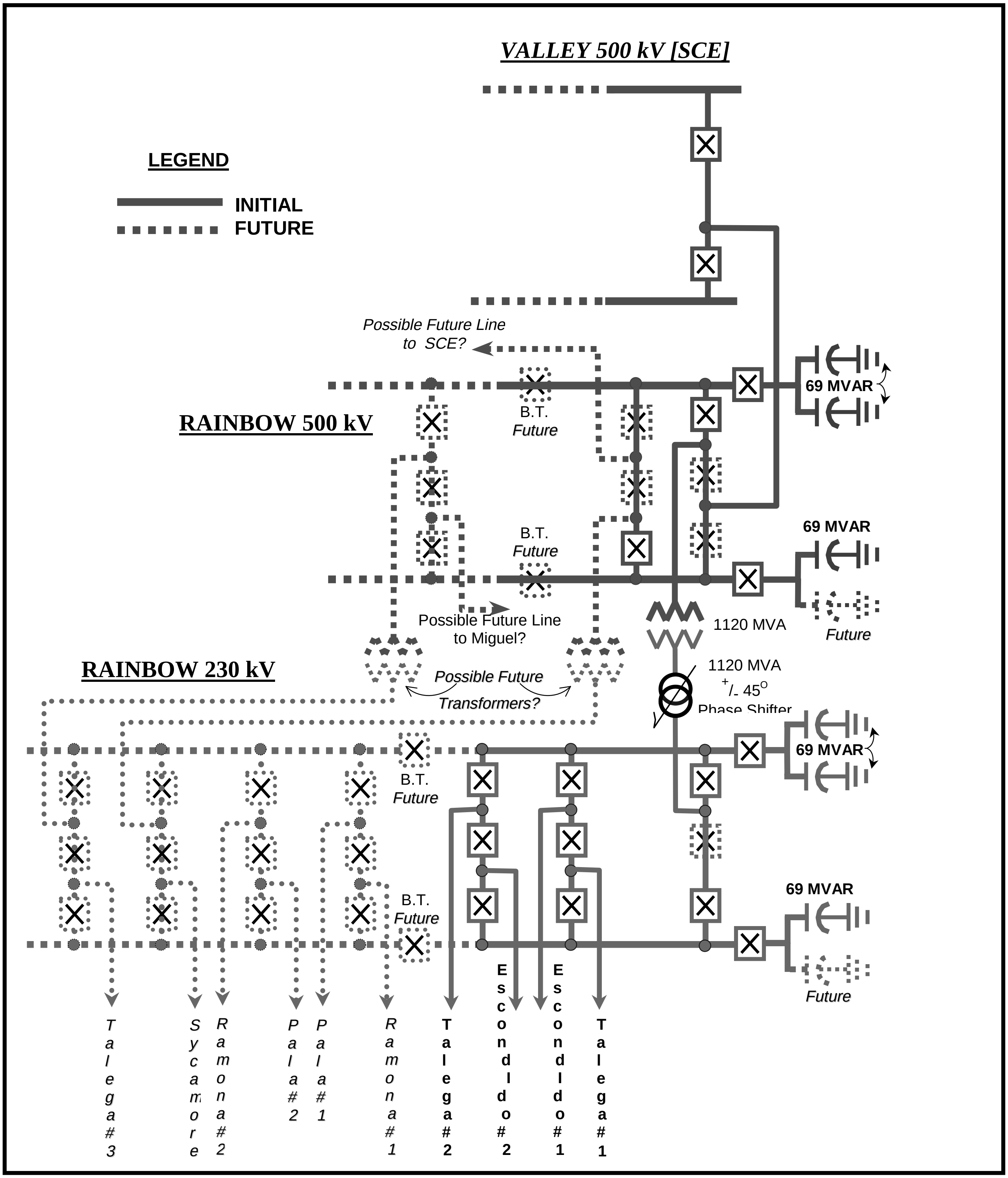
[4] Although some additional upgrade requirements were seen during the course of the studies, such upgrades are not directly required due to the Valley – Rainbow Interconnection Project, but rather due to load growth and the need for greater import. These facility requirements will be addressed under the annual SDG&E grid assessment study. Such projects include the following:

- Install a new 392 MVA 230 kV to 138 kV Tap Changing Under Load (TCUL) transformer (similar to the one at Miguel Substation) at Sycamore Canyon Substation, which would require the development of a 138 kV bus at Sycamore Canyon Substation. This new transformer at Sycamore Canyon Substation not only supports the dissemination of power from Rainbow or Pala into the 138 kV system, but also supports the change in flow pattern caused by the lower generation dispatch allowed by anticipated higher imports.
- Loop-in the existing Chicarita - Carlton Hills Tap 138 kV Line (TL13821) into the new 138 kV bus at Sycamore Canyon Substation (described above).
- Bundle the existing San Luis Rey - Mission 230 kV Line (TL23002) and the new San Luis Rey - Mission 230 kV #2 Line formed after the 2002 San Luis Rey Substation expansion project with 2-1033 kCMIL ACSR per phase. The 2002 San Luis Rey Substation expansion project loops in the existing 230 kV line from SONGS to Mission (TL23006) into a new San Luis Rey 230 kV bus.
- Develop a continuous emergency rating for the Encina - Peñasquitos 230 kV Line (TL23012) of approximately 2800 Amps.
- Some local transmission system reinforcements will be needed in the Escondido 69 kV area. Some of the thermal problems along existing 69 kV transmission lines include: Escondido - Bernardo Tap, Escondido - Felicita Tap, Escondido - Ash, and Escondido - Lilac.

[5] To minimize project costs, a transformer-terminated line may be utilized rather than constructing a 500 kV bus arrangement at Rainbow Substation. If so, additional 230 kV capacitors would be constructed in place of 500 kV capacitors. The proposed 230 kV bus arrangement is a “breaker-and-a-half” configuration. There would be no measurable impact on overall project performance.

**Figure 2**
## Rainbow or Pala Substation Ultimate Design



- Install two 500 kV to 230 kV transformers with 700 MVA capability each for the Rainbow or Pala site, along with two 230 kV phase-shifting transformers of approximately 700 MVA capability each operating in parallel (or FACTS devices to similarly control flow). Studies show that an angle of approximately 30 degrees is needed to control 1000 MW of flow under heavy load and heavy import conditions. The study modeled a range of -45° to 45°, but further study might be needed to optimize the range. SDG&E Substation Design is also investigating the economics and practicality of having one transformer bank similar to the Miguel 500/230 kV transformer bank with a nameplate rating of 1120 MVA, along with a 230 kV phase shifting transformer of comparable rating.

- Loop-in the existing Talega – Escondido 230 kV Line (TL23030) into Rainbow or Pala to form Talega – Rainbow/Pala and Rainbow/Pala - Escondido 230 kV Lines, and bundle[6] with 2-1033 kCMIL ACSR per phase. In addition, add second Talega – Rainbow/Pala and Rainbow/Pala - Escondido 230 kV circuits, bundled as the others. These changes strengthen the system thermally and lower the phase-shifting angle requirement by 5 degrees.

- A comparative assessment of the voltage support requirement indicates that at least the following will be needed to achieve a 3600 MW level of import for all of the “Rainbow Alternatives”:
  - installation of STATCOM or similar equipment with a dynamic reactive power response capability at the following locations:
    - Sycamore Substation 230 kV bus, +/- 100 MVAR capability;
    - Talega or Escondido Substation 230 kV bus, +/- 100 MVAR capability; and
    - Mission Substation 230 kV bus, +/- 150 MVAR capability.
  - installation of three 69 MVAR shunt capacitor banks at the Rainbow or Pala Substation 500 kV bus;
  - installation of three 69 MVAR shunt capacitor banks at the Rainbow or Pala Substation 230 kV bus;
  - installation of one 69 MVAR shunt capacitor banks at the San Luis Rey Substation 230 kV bus;
  - installation of two 69 MVAR shunt capacitor banks at the Sycamore Canyon Substation 230 kV bus;
  - installation of one 43 MVAR shunt capacitor banks at the Telegraph Canyon Substation 138 kV bus;

[6] Use of unbundled Talega – Rainbow – Escondido 230 kV conductors may be possible if an increased emergency rating is determined to be feasible, or the scheduled flow on the Valley – Rainbow 500 kV line is limited slightly. Avoidance of bundling results in a minor increase of phase shifter angle requirements or UPFC sizing.

- installation of one 50 MVAR shunt capacitor banks at the Sweetwater Substation 69 kV bus (or alternative 69 kV bus at South Bay or Silvergate Substation);
- installation of two 69 MVAR shunt capacitor banks at the Mission Substation 230 kV bus;
- installation of one 69 MVAR shunt capacitor banks at the Miguel Substation 230 kV bus; and
- installation of one 69 MVAR shunt capacitor banks at the Escondido Substation 230 kV bus.

The required reactive support required totals 350 MVAR of dynamic reactive power support and 990 MVAR of static reactive power support.

The following facility additions have been identified for the Second SWPL Alternative[7]:

- a 500 kV line from the existing APS Palo Verde Substation 500 kV bus to Miguel Substation 500 kV bus (approximately 280 miles) with an intermediate connection at Imperial Valley Substation. Adding a new 500 kV line will require the development of a 500 kV bus at Miguel Substation (a bundled 2156 ACSR conductor is presently assumed, but further analysis during the design phase may optimize the conductor type and size);

- a new 1120 MVA 500 kV to 230 kV TCUL transformer at Miguel Substation (consisting of 3 single phase units similar to the existing);

- a second Miguel – Mission 230 kV Line;

- a second Miguel – Sycamore Canyon 230 kV Line;

- a additional 224 MVA 230/69 kV TCUL transformer at Mission Substation; and

- The amount of reactive power support required for the second SWPL alternative is on the order of 1000-1350 MVAR, with at least 30% of it being dynamic.

For the second SWPL alternative the feasibility of achieving sufficient separation to eliminate common corridor contingency (N-2) exposure is undetermined at this time.

[7] Other upgrades, such as a new 230/138 kV Transformer at Sycamore Canyon Substation and a loop-in of the existing Chicarita - Carlton Hills Tap 138 kV Line (TL13821) into the new 138 kV bus at Sycamore Canyon Substation may also be required. As described earlier, such upgrades are not directly required due to the second SWPL Alternative, but rather due to load growth and the need for greater import. These facility requirements would be addressed under the annual SDG&E grid assessment study.

If according to the WSCC requirements the common corridor contingency is credible, the usefulness of the second SWPL alternative is significantly reduced.

**Voltage Stability Conclusions**

GE study results show that the point of voltage collapse (e.g., on the Q-V nose curve) is increased closer to the normal operating range as a result of increasing SDG&E import level. However, it is important to note that voltages are poor indicators of voltage stability. The amount of margin (real or reactive) is the most important measure of voltage stability.

SDG&E will be installing a mixture of static and dynamic reactive power support to maintain adequate MVAR margins. All of the capacitors will be equipped with relays and control logic so that they can be turned on and off without reliance on operator action. The operation of capacitors will be automatically coordinated with the dynamic reactive power support devices such that during heavy load and import conditions a maximum amount of capacitors will be turned on pre-contingency. This will allow operating local generating units at near unity power factor pre-contingency, thereby allowing emergency/dynamic reactive power reserves to be carried by the generators and FACTS devices strategically located throughout the SDG&E system. The number, size, and location of capacitor banks and FACTS devices will be selected to optimize system operation. The FACTS devices will provide automatic regulation such that the need for capacitor switching is minimized. Having a maximum amount of capacitors on line (pre-contingency) will ensure that the reactive power margin will be available when needed. This will:

(1) minimize or eliminate the need for operator action following contingencies;
(2) maximize the reactive power operating margin; and
(3) maintain system security.

In addition to the above measures, SDG&E will also re-evaluate its reactive power margin criteria to determine if additional margin would be required in 2004 to further minimize the potential for voltage collapse. In addition, as suggested by General Electric, SDG&E will investigate the use of line drop compensation for Encina and South Bay power plants with the plant owners.

## RECOMMENDED ACTIONS

- Pending ISO approval, SDG&E should prepare for filing an application with the California Public Utilities Commission for a Certificate of Public Convenience and Necessity (CPCN) for the Valley-Rainbow project.

- SDG&E should proceed with Phase 2 of the WSCC Path Rating Approval Process for the Valley-Rainbow 500kV line and initiate formation of a path rating review group.

- In parallel with the WSCC Phase 2 study, SDG&E should pursue the following items:
  - Determine the proper mix of static and dynamic reactive power compensation additions, optimum VAR locations, choice of preferred compensation technologies (capacitors, SVCs, FACTS devices, etc.), and re-evaluate SDG&E reactive power margin criteria to ensure voltage stability.
  - Study simultaneous loading impacts, particularly the Southern California Import Transmission (SCIT) path.
  - Demonstrate project compliance with WSCC Level A, B and C contingencies.
  - Evaluate the suitability of a Unified Power Flow Controller (UPFC) as an alternative to the proposed 1400MVA phase-shifter at Rainbow/Pala, and assess the pros and cons of installing either device at 500kV versus 230kV.
  - Complete assessment of Pala Substation as an alternative to the Rainbow site.
  - Finalize the internal SDG&E 230, 138 & 69kV facility expansion plans needed to support the Valley-Rainbow Project.
  - Identify all significant operational procedures that need to be developed to integrate the project into the Regional grid.
  - Investigate the use of line drop compensation with Encina and South Bay plant owners as a possible way to further improve system voltage stability.
  - Study simultaneous loading impacts on SDG&E and CFE imports.
  - Study an off-peak or “shoulder” peak load case (minimum generation on-line in SDG&E).

## OVERVIEW AND CONSTRAINTS OF SECOND SWPL ALTERNATIVE

A second SWPL line would involve acquisition of at least 280 miles of right-of-way, assuming the line is built adjacent to SWPL by widening the existing corridor in order to add a second 500kV line on new structures. If it were necessary to locate the line on completely separate right-of-way to prevent common corridor outage exposure, it is anticipated that the mileage requirements would increase to approximately 350 miles. A completely independent route may not be available without crossing the international border into Mexico, but we have done no evaluation of the feasibility of such an option.

At this time SDG&E has not conducted analysis of alternative corridors separate from the existing SWPL corridor. However, SDG&E has had discussions with a reliable third party that recently investigated transmission right-of-way options from Palo Verde to the west side of the Colorado River. They have concluded that there is approximately a 50 mile segment in the Yuma area that must be adjacent to the existing SWPL corridor. Essentially no work has been done on corridor options through the Imperial Valley, but agricultural use issues are likely to be a significant impediment.

Given the length of the line and the complexity of permitting, land use and environmental issues affecting the project, it is highly unlikely that the licensing and construction of a second SWPL line could be accomplished before 2006-2007. Licensing, right-of-way acquisition and construction on a new corridor separated from the existing line, if found to be feasible, is likely to add another 1-2 years to the project lead-time.

## BASE CASE DEVELOPMENT

Four sets of cases were developed, based on the Heavy Summer case developed by the Cal-ISO for the 2004 Composite Study, with the SDG&E and SCE areas represented to reflect their 1999 annual assessment studies for the year 2004. Each set includes a benchmark case and three Rainbow (or Pala) alternatives as well as the second SWPL alternative. The cases were:

1. 80/20 load with all facilities in service (for thermal, stability and post-transient studies);
2. 50/50 load and a SONGS unit out-of service (for G-1/N-1 VAR margin studies);
3. 50/50 load and two SONGS units in-service (for N-2 VAR margin studies); and
4. 80/20 load and SWPL out of service (for N-1-1 thermal studies).

Heavy Summer conditions have been examined for the initial studies, although subsequent studies in Phase 2 of the WSCC rating process (if this Project is pursued) may include other seasons at the request of WSCC members. June 2004 continues to be the Project's tentative target in-service date. Though ways to achieve this date will continue to be investigated, slippage of the in-service date is possible.

The loads in the Composite Study, also used in this study, are based on the one-in-five-year ("80/20") adverse weather loads from the California Energy Commission (CEC) forecast. Reactive power margin studies were performed using the most recent one-in-two-year ("50/50") load forecast available at the commencement of the study, the 1999 load forecast.

The 2004 Heavy Summer base case represents the following modeling parameters:

1. Flows on major WSCC interconnection paths have been kept within reasonable ranges to eliminate simultaneous constraints, in order to determine a non-simultaneous rating;
2. The most up-to-date load models and Watt-to-Var ratios for the year 2004 have been used for the SDG&E and SCE systems:
   - SCE: 21,442 MW peak load[8] (based on the 80/20 CEC forecast, 22,179 MW including losses and pump load) and 25:1 WATT/VAR leading ratio (0.999 leading power factor on the 230 kV side); and
   - SDG&E: 4645 MW peak load (based on the 80/20 CEC forecast, 4741 MW including losses) and 8:1 WATT/VAR ratio (0.992 lagging power factor).
3. Other load, resource, inertia, spinning reserve and inter-area scheduling data reflect a peak Heavy Summer day.
4. In accordance with the WSCC criteria established for voltage margin and voltage stability studies, loads were modeled at the 50/50 level for this type of study.
   - SCE: 20,734 MW load (21,495 MW including losses and pump load) and 12.5:1 WATT/VAR leading ratio (0.9967 leading power factor on the 230 kV side); and

[8] Of the 21732 MW of load in the SCE area, 21442 is the load exclusive of pump load, which is an additional 290 MW.

- SDG&E: 4593 MW load (4687 MW including losses) and 8:1 WATT/VAR ratio (0.992 lagging power factor).

No modeling of fictitious facilities was used in demonstrating that the WSCC Criteria are met. The GE-PSLF version 11 software was used for the power flow and transient stability studies. Except as noted, series compensation levels in the major EHV lines were represented at their normal levels, which is as follows:

| ***EOR EHV Lines*** | ***Series Compensation*** | |
|---|---|---|
| Navajo - McCullough | 500 kV | 70% |
| Moenkopi - Eldorado | 500 kV | 70% |
| Liberty - Mead | 345 kV | 70% |
| Palo Verde - Devers | 500 kV | 50% |
| Palo Verde - North Gila | 500 kV | 50% |
| Westwing - Perkins - Mead | 500 kV | 70% |

| ***WOR EHV Lines*** | ***Series Compensation*** | |
|---|---|---|
| McCullough - Victorville #1 | 500 kV | 35% |
| McCullough - Victorville #2 | 500 kV | 35% |
| Eldorado - Lugo | 500 kV | 35% |
| Mohave - Lugo | 500 kV | 26% |
| North Gila - Imperial Valley | 500 kV | 50% |
| MarketPlace – Adelanto | 500 kV | 45% |

The Palo Verde – North Gila line compensation was modeled as by-passed once the projects were put in service. This was needed to eliminate the limitation of the series capacitors.

The Imperial Valley – Miguel 500 kV Line has been represented at its normal series compensation level, which is 50%.

All proposed projects which are in Phase 2 or 3 of the WSCC rating process and are expected to be in service prior to the summer of 2004 have been represented in the base case.

As in the Cal-ISO Composite study, and the SONGS Phase II Study, all planned generating resources that currently have site licenses and System Impact Studies approved by Cal-ISO were included in the cases.

Summaries of the cases can be found in Appendix A.

## STUDY METHODOLOGY

All analyses were performed using the GE PSLF package, version 11.0 package and special “EPCLs”. GE Power System Energy Consulting performed all Reactive Power Margin Studies, Transient Stability Studies and all studies related to use of a FACTS device to control the flow. Base case preparation and thermal analysis were performed jointly by SDG&E and SCE.

Studies were performed to assess the system performance with and without the Project facilities added. Cases were tested to ensure compliance with all applicable reliability criteria, including the Cal-ISO Grid Planning Criteria, WSCC Reliability Criteria, and NERC Planning Standards.

Four sets of cases were developed, based on the Heavy Summer case developed by the Cal-ISO for the 2004 Composite Study, with the SDG&E and SCE areas represented to reflect their 1999 annual assessment studies for the year 2004. Each set includes a benchmark case and three Rainbow (or Pala) alternatives as well as the second SWPL alternative. The cases were:

- 80/20 load with all facilities in service (for thermal, stability and post-transient studies);
- 50/50 load and a SONGS unit out-of service (for G-1/N-1 VAR margin studies);
- 50/50 load and two SONGS units in-service (for N-2 VAR margin studies); and
- 80/20 load and SWPL out of service (for N-1-1 thermal studies).

The three alternatives that would terminate at Rainbow (or nearby Pala) include the following:

- Valley - Rainbow case;
- Devers - Rainbow case; and
- Mira Loma - Rainbow case.

The benchmark cases were used to establish the need for the project and to benchmark the performance of the system. The other four cases, each modeling one of the alternatives under consideration, were used to compare the alternatives against each other. All post-project cases were benchmarked at 3600 MW of imports into SDG&E except the SWPL out-of-service cases. Printouts of all the nineteen cases can be found in Appendix B.

### All-facilities-in-service 80/20 load set of cases

These cases have an 80/20 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite study.

SDG&E and SCE imports were represented at a high level, representing a typical Heavy Summer condition. The SCIT and EOR levels are also representative of Heavy Summer conditions. The addition of any of the proposed alternatives increases the SCIT flows. The table in Appendix A contains a summary for each case.

The cases with all-facilities-in-service were used to conduct thermal contingency analysis. Contingency Analysis included all N-1 (lines, transformers and generators) in the SDG&E and SCE systems as well as credible N-2 outages in both systems. The objective in studying these cases is to identify the major thermal upgrades required for each alternative. Some fine-tuning will be required in the SDG&E system as more detailed studies are pursued during the annual assessment.

Some post-transient studies of these cases have been performed, but additional effort in this area will be deferred to a later phase since the objective now is to compare alternatives rather than achieving ultimate design for each of the alternatives. Post-transient studies require a more detail design of the reactive power additions.

**50/50 load and one SONGS unit out-of-service set of cases**

These cases have 50/50 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite study.

SDG&E and SCE import level are high representing a typical Heavy Summer condition. The SCIT and EOR levels are also representative of Heavy Summer conditions. The addition of the any of the proposed alternatives increases the SCIT flows. The table in Appendix A contains a summary for each case.

These cases have one SONGS unit out of service and all-lines in service. The objective with these cases is to do reactive power margin studies consistent with the WSCC reactive planning criteria as established in "Voltage Stability Criteria, Undervoltage Load Shedding Strategy, and Reactive Power Reserve Monitoring Methodology"

These cases were used by GE to evaluate the reactive power margin for the different alternatives. The study looked at the most critical N-1 contingencies.

**50/50 load set of cases and two SONGS units in service**

These cases have 50/50 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite study.

SDG&E and SCE import levels are high representing a typical Heavy Summer condition. The SCIT and EOR levels are also representative of Heavy Summer conditions. The addition of the any of the proposed alternatives increases the SCIT flows. The table in Appendix A contains a summary for each case.

These cases have two SONGS units in service and all-lines in service. The objective with these cases is to do reactive power margin studies for N-2 consistent with the

WSCC reactive planning criteria as established in "Voltage Stability Criteria, Undervoltage Load Shedding Strategy, and Reactive Power Reserve Monitoring Methodology"

These cases were used by GE to evaluate the reactive power margin for the different alternatives. The study looked at the three most critical N-2 contingencies:

- Loss of both SONGS units
- Loss of the Lugo – Mira Loma 2&3 500 kV lines
- Loss of SWPL #1 and #2 500 kV lines

**SWPL out-of-service set of cases**

These cases have an 80/20 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite Study. These cases were studied to analyze the system under the Cal-ISO grid planning reliability criteria. Experience has demonstrated that the most critical condition is having SWPL out of service, followed by loss of another system element.

Today SDG&E import level is adjusted when SWPL is out of service. When a segment of SWPL is out of service most of the import (depending on the segment that opened) into SDG&E flows on the South of SONGS path. After implementation of any of the alternatives, the total import into San Diego, when SWPL is out of service, will be carried by the new line plus the South of SONGS path. The study of these cases included the thermal analysis to determine the import level achievable and the system upgrades required for SWPL out of service. The table in Appendix A contains a summary for each case.

The analysis included all possible subsequent outages N-1 (lines, transformers and generators) in the SDG&E and SCE systems. The objective in this study was to identify the major thermal upgrades or import reductions required for each alternative. Some fine-tuning will be required in the SDG&E system as more detailed studies are pursued to achieve an ultimate design for each of the alternatives.

## DETAILED STUDY RESULTS

### *SDG&E System Thermal Analysis*

Thermal analysis consisting of base case and contingency analysis was performed. Contingency analysis consisted of examination of single contingencies (N-1), double contingencies (N-2), and overlapping contingencies (N-1-1). Based on the Cal-ISO Grid Planning Criteria, loss of a generator, with the system adjusted, followed by loss of a single transmission line (G-1 / N-1) should be treated as a single contingency.

In assessing the value of the Valley – Rainbow proposal, or any alternative proposal, in terms of the reliability benefit it brings, one needs to consider that the system does not meet the G-1 / N-1 criteria prior to the addition of the Project. The Project not only serves the reliability needs in 2004 out to approximately 2006, but brings the system up to the Cal-ISO reliability standard.

The "all-lines-in-service 80/20 load set of cases" was used for N-1 and N-2 analysis; the "SWPL out-of-service set of cases" was used for N-1-1 analysis. A list of the contingencies studied for the SDG&E system is shown in Appendix C. Both sets of cases used for thermal analysis have an 80/20 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite study.

The objective in studying these cases is to examine system performance and identify the major thermal upgrades required for each alternative.

<u>All-lines in-service cases (SDG&E Cases)</u>

Base case analysis of the "Rainbow alternatives" shows that for SDG&E imports at 3600 MW with typical heavy summer EOR flows higher than 3500 MW, the series capacitors for a segment of SWPL, either the Palo Verde – North Gila segment or the North Gila – Imperial segment, should be by-passed to avoid overloading of the series capacitors.

The cases used for the contingency analysis, summarized in the tables, include some preliminary upgrades. Such upgrades include bypassing the SWPL series capacitors, bundling the Rainbow – Talega and Rainbow – Escondido lines and adding second circuits, and adding a phase-shifting transformer at Rainbow Substation. The upgrades also include adding 407 MVAR of reactive power support at Rainbow Substation (200 MVAR on the 500 kV bus and 207 MVAR at the 230 kV bus) and adding a new 230/138 kV transformer at Sycamore Canyon Substation. The initial amount of reactive power support added to the cases was the minimum required to allow the cases to solve for SWPL outages.

Table 3 on the next page shows a summary of the N-1 contingency analysis in the SDG&E area. The column labeled Comments summarizes the resolution to the overloads. The Encina - Peñasquitos 230 kV Line (TL23013) shows an overload for three contingencies (loss of any segment of SWPL). Currently, this line is limited by a 2000-Ampere circuit breaker rating, and a continuous emergency rating of the conductor has been established to be at least 2290 Amperes. The terminal breaker arrangement at the Encina Substation 230 kV side is breaker-and-a-half, the arrangement on the other end (Peñasquitos) is double breaker. The line conductor is 2-1109 kCMIL ACSR, which has a normal rating of 2290 Amperes.

These upgrades described above were found necessary in initial screening studies. Table 3 also shows that for loss of one of the two Peñasquitos Substation 230/69 kV transformers, the remaining transformer is within the acceptable loading limit. A previous run without the Sycamore Substation 230/138 kV transformer showed higher loading (105% their continuous emergency rating) for N-1.

The overloads observed in the last seven lines of the table, as well as the ones in the B-Kettner-Old Town 69 kV system will be resolved during the SDG&E annual assessment.

Table 4 shows the results of N-2 analysis for the SDG&E area. Most of the problems found in the “Rainbow Alternatives” are either existing, due to load growth, or already being addressed under the N-1 analysis. Table 4 shows that for the second SWPL alternative, power out of Miguel Substation causes high loading in the Miguel Substation transformers as well as the 138 kV system out of Miguel. These loading problems have been solved by adding a second Miguel – Mission 230 kV Line, a second Miguel – Sycamore Canyon 230 kV Line, and a new 224 MVA 230/69 kV TCUL transformer (similar to the existing ones) at Mission Substation.

Table 3 and Table 4 clearly illustrate the similarity among the Rainbow alternatives.

Table 3: **N-1 Contingency Analysis for SDG&E (all lines in service cases)**
**Valley – Rainbow Feasibility Study**

| **Outage** | **Overloaded Element** | **MVA Rating *** | **Loading based on MVA Rating** | | | | | **Comment** |
|---|---|---|---|---|---|---|---|---|
| | | | **Base** | **RD** | **RM** | **VR** | **2sw** | |
| 500.0kV line to RAINBOW | NONE | | N/A | | | | | Most loaded line PV-NG at around 1475 Amps / 1277MVA (1) |
| N.GILA - IMPRLVLY 1 500.0kV | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.17 | 1.02 | 1.11 | | Below Emergency Rating for N-1 (2) |
| | PENSQTOS 230 - ENCINA 230 1 | 797 | | 1.03 | 1.02 | 1.02 | | Below Emergency Rating of 2290 Amps / 912 MVA (3) |
| PALOVRDE - N.GILA 1 500.0kV | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.2 | 1.04 | 1.13 | | Below Emergency Rating for N-1 (2) |
| | PENSQTOS 230 - ENCINA 230 1 | 797 | | 1.01 | 1 | 1 | | Below Emergency Rating of 2290 Amps / 912 MVA (3) |
| PENSQTOS - ENCINA 1 230.0kV | ESCNDIDO 69 - BERNDOTP 69 1 | 102 | | 1.05 | 1.04 | 1.04 | | Will be addressed In annual assessment |
| PENSQTOS - PENSQTOS 1 69/230kV | PENSQTS 230 - PENSQTOS 69 2 | 269 | | 1.01 | 1.01 | 1.01 | 1.01 | Acceptable |
| MIGUEL - MIGUEL 1 69/230 kV | MIGUEL 69 - MIGUEL 230 kV 2 | 305 | | | | | 1.01 | At Limit, Acceptable |
| MIGUEL - MIGUEL 2 69/230 kV | MIGUEL 69 - MIGUEL 230 kV 1 | 305 | | | | | 1.01 | At Limit, Acceptable |
| IV-MG 500kV / MG-TJ 230kV | ENCINA - PENSQTOS 230kV | 798 | | 1.11 | 1.11 | 1.1 | | Below Emergency Rating of 2290 Amps / 912 MVA (3) |
| | B - KETTNER 69kV | 194 | | 1.09 | 1.08 | 1.08 | | These three lines will be addressed in annual assessment |
| | KETTNER - OLDTOWN 69kV | 237 | | 1.05 | 1.05 | 1.05 | | |
| | BERNDOTP - ESCNDIDO 69kV | 100 | | 1.04 | 1.04 | 1.04 | | |
| IMPRLVLY - ROA-230 1 230.0kV | TJI-230 230 - TJI-69 69 2 | 100 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 | 100 MVA is the Normal Rating Emergency Rating is at least 115% |
| MIGUEL - TJI-230 1 230.0kV | TJI-230 230 - TJI-69 69 2 | 100 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 | 100 is the Normal Rating Emergency Rating is at least 115% |

* MVA Rating refers to the rating modeled in the power flow simulations.

Table 3 (continued): **N-1 Contingency Analysis for SDG&E (all lines in service cases)**
**Valley – Rainbow Feasibility Study**

| Outage | Overloaded Element | MVA Rating * | Loading based on MVA Rating | | | | | Comment |
|---|---|---|---|---|---|---|---|---|
| | | | Base | RD | RM | VR | 2sw | |
| ESCNDIDO - ASH 1B 69.0kV | ESCNDIDO 69 - FELCTATP 69 1 | 102 | | 1.07 | 1.07 | 1.07 | | Will be addressed In annual assessment |
| ESCNDIDO - FELICITA 1 69.0kV | ESCNDIDO 69 - FELCTATP | 102 | | 1.08 | 1.08 | 1.08 | | Will be addressed In annual assessment |
| FE-AS-VC 69.0kV | ESCNDIDO 69 - LILAC 69 1 | 68 | | 1.01 | 1.02 | 1.02 | | Will be addressed In annual assessment |
| MELROSE - SANLUSRY 1 69.0kV | MELRSETP 69 - SANLUSRY 69 1 | 102 | 1.23 | 1.14 | 1.13 | 1.13 | | Existing problem switching scheme in place |
| PENDLETN - SANLUSRY 1 69.0kV | MORHILTP 69 - SANLUSRY 69 1 | 102 | 1.01 | | | | 1.01 | Existing problem switching scheme in place |
| ES-BE-FE 69.0kV | ESCNDIDO 69 - BERNDOTP 69 1 | 102 | | 1.04 | 1.03 | 1.03 | | Existing problem switching scheme in place |
| * MVA Rating refers to the rating modeled in the power flow simulations. | | | | | | | | |

(1) Emergency Rating is 1890 Amps / 1636 MVA
(2) Palo Verde - Devers 500 kV has an Emergency Rating of 2430 Amps / 2104 MVA for N-1 contingencies
(3) Re-rating based on conductor rating 2290 Amps / 912 MVA

Table 4: **N-2 Contingency Analysis for SDG&E (all lines in service cases)**
**Valley – Rainbow Feasibility Study**

| Outage | Overloaded Element | MVA Rating * | Loading based on MVA Rating | | | | | Comment |
|---|---|---|---|---|---|---|---|---|
| | | | Base | RD | RM | VR | 2sw | |
| EA-BQ-PQ + EA-CAN 138KV | CALAVRTP 138 - SHADOWR 138 1 | 112 | 1.11 | | | | | |
| | CHCARITA 138 - CARLTHTP 138 1 | 204 | 1.09 | | | | | |
| | CHCARITA 138 - SYCAMORE 138 1 | 204 | | 1.05 | 1.05 | 1.05 | 1.05 | More study work is being done (1) |
| | ESCNDO50 138 - ESCNDIDO 69 2 | 82 | 1 | | | | | |
| | MISSION 138 - CARLTNHS 138 1 | 273 | 1.08 | | | | | |
| ES-EA-SA + SY-ES 230KV | ESCNDIDO 69 - BERNDOTP 69 1 | 102 | | 1.05 | 1.04 | 1.04 | | Also seen in N-1 |
| MI50-SY + MS-SY 138KV | MAINST51 138 - MAIN ST 69 1 | 199 | 1.02 | | | | | |
| | SOUTHBAY 69 - SOUTHBAY 138 1 | 164 | 1.01 | | | | | |
| MI51-SY + MS-SY 138KV | SOUTHBAY 69 - SOUTHBAY 138 1 | 164 | 1.08 | | | | | |
| ML-SY + ML-MS 230KV | MIGUEL 230 - MIGUEL 138 1 | 468 | | | | | 1.42 | These overloads are being |
| | MIGUEL 69 - MIGUEL 230 1 | 305 | | | | | 1.10 | Addressed for the second SWPL |
| | MIGUEL 69 - MIGUEL 230 2 | 305 | | | | | 1.10 | Alternative by a 230 kV line |
| | PARADISE 69 - CHOLLAS 69 1 | 101 | | | | | 1.27 | From Miguel to Mission and a |
| | PRCTRVLY 138 - MIGUEL 138 1 | 469 | | | | | 1.38 | 230 kV line from Miguel to |
| | PRCTRVLY 138 - TELECYN 138 1 | 408 | | | 1.03 | 1.01 | 1.52 | Sycamore Canyon |
| | TELECYN 138 - SOUTHBAY 138 1 | 408 | | | | | 1.42 | |
| | MIGUEL 69 - GRANITTP 69 1 | 102 | | | | | 1.11 | |
| | EL CAJON 69 - JAMACHA 69 1 | 137 | | | | | 1.06 | |
| PQ-EA 230 KV + EA-NCW 138 KV | CARLTHTP 138 - SYCAMORE 138 1 | 204 | | 1.03 | 1.03 | 1.03 | | More study work is being done (1) |
| | ESCNDIDO 69 - BERNDOTP 69 1 | 102 | | 1.09 | 1.08 | 1.08 | | Also seen in N-1 |
| PQ-EA 230 KV + NCW-PQ 138 KV | CARLTHTP 138 - SYCAMORE 138 1 | 204 | | 1.01 | 1.01 | 1.01 | | More study work is being done (1) |
| | ESCNDIDO 69 - BERNDOTP 69 1 | 102 | | 1.08 | 1.07 | 1.07 | | Also seen in N-1 |
| PQ-NCW + EA-BQ-PQ 138KV | CALAVRTP 138 - SHADOWR 138 1 | 112 | 1.14 | | | | | |
| | ESCNDO50 138 - ESCNDIDO 69 2 | 82 | 1.04 | | | | | |

Table 4 (continued): **N-2 Contingency Analysis for SDG&E (all lines in service cases)**
**Valley – Rainbow Feasibility Study**

| Outage | Overloaded Element | MVA Rating * | Loading based on MVA Rating | | | | | Comment |
|---|---|---|---|---|---|---|---|---|
| | | | Base | RD | RM | VR | 2sw | |
| SA-MS 1 + SA-MS 2 230KV | PENSQTOS 230 - ENCINA 230 1 | 797 | | 1.06 | 1.04 | 1.04 | | Below Emergency Rating of 2290 Amps / 912 MVA |
| SA-SO 1 + SO-SA 2 230KV | SANLUSRY 230 - S.ONOFRE 230 n | 912 | | 1.06 | 1.04 | 1.04 | 1.15 | Below Emergency Rating of 2808 Amps / 1120 MVA |
| SOUTHBAY 138 CORRIDOR | LOSCOCHS 138 - SOUTHBAY 138 1 | 204 | 1.05 | | | | | Existing problem |
| | SAMPSON 69 - DIVISION 69 1 | 101 | 1.18 | | | | | Existing problem |
| | SOUTHBAY 69 - SOUTHBAY 138 1 | 164 | 1.45 | 1.16 | 1.17 | 1.17 | | Existing problem |
| | PARADISE 69 - CHOLLAS 69 1 | 101 | | | | | 1.04 | Existing problem |
| TA-TB + TA-PI 138KV | SANMATEO 138 - LAGNA NL 138 1 | 112 | 1.10 | 1.10 | 1.09 | 1.09 | 1.09 | Existing problem |
| | TALEGA 138 - SANMATEO 138 1 | 137 | 1.14 | 1.14 | 1.14 | 1.13 | 1.14 | Existing problem |
| TA-SO 1 + 2 230 KV | JAP MESA 69 - TALEGATP 69 1 | 24 | 1.06 | | | | 1.04 | Existing problem |
| | LASPULGS 69 - HORNO TP 69 1 | 32 | 1.04 | | | | 1.02 | Existing problem |
| | OCNSDETP 69 - STUARTTP 69 1 | 32 | 1.23 | | | | 1.21 | Existing problem |
| | STUARTTP 69 - LASPULGS 69 1 | 32 | 1.15 | | | | 1.13 | Existing problem |

* MVA Rating refers to the rating modeled in the power flow simulations.

(1) An Emergency Rating for Chicarita – Carlton Hills and Chicarita – Sycamore Canyon is being investigated. The planning criteria allows load dropping for the condition; however, a short- or long-term emergency rating would be the preferred solution.

<u>SWPL out-of-service (SDG&E Cases)</u>

These cases have an 80/20 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite Study. These cases were studied in order to analyze the system under N-1-1 conditions (an initial N-1, system readjusted, and subsequent N-1). Prior Southern California regional studies have demonstrated that SWPL out of service, followed by any other element presents the most critical condition today. Further assessment was done after adding the new 500 kV line, and results indicated that SWPL initially out of service is the most limiting N-1 event.

Today, the SDG&E import level is adjusted when SWPL is out of service. When a segment of SWPL is out of service, most of the import (depending on the segment of SWPL that opened) into SDG&E flows on the South of SONGS path. After implementation of any of the alternatives, the total import into San Diego, when SWPL is out of service, will be carried by the new line plus the South of SONGS path. The study of these cases included the thermal analysis to determine the import level achievable and the system upgrades required for a segment of SWPL out-of-service.

Contingency Analysis on a case (for each alternative) with Imperial Valley – Miguel 500 kV and Miguel – Tijuana 230 kV lines out-of service was performed. The objective in studying these cases was to identify the major thermal upgrades required for each alternative and the import reduction required to meet the grid planning reliability criteria. Some fine-tuning will be required in the SDG&E system as more detailed studies are pursued to achieve an ultimate design for each of the alternatives.

Studies show that for SWPL out-of service and the system readjusted, the SDG&E imports have to be lowered for the Valley – Rainbow and the Devers - Rainbow alternative. For these two cases, the SDG&E import was lowered to 3400 MW, and the phase shifter was set to control 400 MW of flow in the Valley - Rainbow alternative, and 300 MW in the Devers - Rainbow alternative.

Initial studies of all the Rainbow alternatives, for SWPL out-of service and the system readjusted, revealed that both San Luis Rey to Mission lines need to be reconductored. The loading on these lines exceeds the emergency rating of 1400 Amps for outage of either one of the lines or for the outage of Encina to Peñasquitos 230 kV line. However, these overloads are not associated with the Valley - Rainbow proposal, since they would occur with sufficiently high imports regardless of whether the Valley – Rainbow Project were constructed.

Table 5 on the next page summarizes the results of the contingency analysis for SWPL initially out of service and subsequent outages for the SDG&E system. The Valley Alternatives already include the bundling of both San Luis Rey to Mission 230 kV lines. The table shows a comparison between the alternatives. The Mira Loma – Rainbow alternatives shows many more overloads on the 69 kV system, since the import level did not need to be reduced to avoid overloading the Palo Verde – Devers 500 kV Line as it was for the Valley – Rainbow and Devers – Rainbow alternatives. These would be investigated further if this alternative were to be pursued. Economic evaluation of the upgrades versus lowering the imports will have to be developed. For the purpose of this study, it was assumed that the import for the Mira Loma – Rainbow alternative will be in the range of 3400 MW to 3600 MW depending on the 69 kV upgrades in place.

For the second SWPL alternative, the feasibility of achieving sufficient separation to eliminate common corridor contingency (N-2) exposure is undetermined at this time. Based on the available information to date, the second SWPL would need to be constructed in the same right-of-way as the existing SWPL from Palo Verde to the Yuma area. Utilization of a completely independent route from Palo Verde to Yuma may not be available without crossing the international border into Mexico, but at this time there is no information as to the feasibility of such a routing. The feasibility of building the remaining portion of the second SWPL from Yuma area to Miguel is still undetermined, and is more doubtful if the new line requires an independent right-of-way. Presently the loss of SWPL is the worst contingency from the voltage stability and thermal overload points of view. SDG&E's simultaneous import capability is limited by the loss of SWPL. The loss of SWPL causes all of the power flow on SWPL to flow on South-of-SONGS lines. Such an outage increases the flow on the South-of-SONGS lines, which can cause significant overloads (depending on import levels) on the facilities in the vicinity of the "South of SONGS" area. The significant increase in flow on the South-of-SONGS lines also causes increased reactive power losses for the SDG&E system.

According to the WSCC Reliability Criteria, the common corridor contingency is credible and must be considered in the contingency analysis. Therefore, the N-2 loss of SWPL is a credible contingency. Since for the second SWPL alternative the N-2 loss of both SWPL lines is still the worst contingency for the SDG&E system, it must be considered in the analysis. From line overload and voltage stability points of view, this N-2 contingency performs the same as the N-1 loss of SWPL would perform in the absence of a second line. Furthermore, the second SWPL alternative causes additional flow on the facilities connected to and near Miguel Substation. Upgrading of the facilities at Miguel and nearby facilities as well other internal upgrades would be required to accommodate the addition of the second SWPL.

Table 5. **N-1-1 Contingency Analysis for SDG&E (SWPL out-of-service cases)**
**Valley – Rainbow Feasibility Study (Page 1 of 3)**

| Outage | Overloaded Element | MVA Rating * | Loading based on ER Rating | | | | | Comment |
|---|---|---|---|---|---|---|---|---|
| | | | Base | MR | DR | VR | 2sw | |
| BASE CASE | PALO VERDE - DEVERS 500 kV | 1645 | | 0.99 | 1.00 | 0.99 | | Acceptable, sets the import limit |
| 500.0kV line to RAINBOW | NONE | | N/A | | | | N/A | No problems identified |
| Second SWPL | B - KETTNER 69 kV | 194 | N/A | N/A | N/A | N/A | 1.12 | Will be addressed during |
| | KETTNER - OLD TOWN 69 kV | 237 | | | | | 1.08 | Annual Assessment |
| | | | | | | | | Reactive power deficiency observed (1) |
| PALOVRDE - DEVERS 1 500.0kV | ELDORADO 500 - LUGO 500 1 | 1386 | | 1.03 | | | | All are within Emergency Rating for N-1-1 |
| | EAGLEMTN 230 - EAGLEMTN 161 1 | 77 | | 1.16 | 1.14 | 1.13 | | |
| | IRON MTN 230 - CAMINO 230 1 | 304 | | 1.04 | 1.02 | 1.02 | | |
| | MIRAGE 115 - TAMARISK 115 1 | 217 | 1.02 | 1.08 | 1.03 | 1.05 | | |
| TALEGA - S.ONOFRE 1 or 2 230.0kV | TALEGA 230 - S.ONOFRE 230 2 or 1 | 578 | 1.13 | | 1.39 | 1.27 | | Existing problem (UPFC or bundling is planned to be proposed) |
| SANLUSRY - MISSION 1 or 2 230.0kV | SANLUSRY 230 - MISSION 230 2 or 1 | 557 | | | | | | Bundling already included in post-project cases |
| One SANLUSRY - SONGS 230.0kV | SANLUSRY 230 - SONGS 230 remaining ones | 912 | 1.05 | 1.12 | 1.16 | 1.14 | | Below Emergency Rating of 2800 Amp (1115 MVA) |
| OLD TOWN 230/ 69kV #1 or #2 | OLD TOWN 230/69 # 2 0r #1 | 269 | | 1.17 | 1.14 | 1.13 | | 150% over name plate rating allowed for N-1-1 |
| SANLUSRY 230/ 69kV #1 or #2 | JAP MESA 69 - TALEGATP 69 1 | 24 | | 1.08 | 1.01 | 1.01 | | Motor Operated Switch will be installed |
| | SANLUSRY 69/230kV #2 or #1 | 301 | | 1.09 | 1.07 | 1.07 | | 150% over name plate rating allowed for N-1-1 |
| PENSQTOS - ENCINA 1 230.0kV | SANLUSRY 230 - MISSION 230 #1 | 557 | 1.01 | | | | | Bundling already included in |
| | SANLUSRY 230 - MISSION 230 #2 | 557 | 1.01 | | | | | post-project cases |
| | BERNARDO 69 - FELCTATP 69 1 | 102 | | | 1.08 | 1.09 | | Will be investigated internally |
| PENSQTOS - OLD TOWN 1 230.0kV | PENSQTOS 230 - PENSQTOS 69 2 | 269 | | 1.06 | 1.02 | 1.02 | | 150% over name plate rating allowed for N-1-1 |
| | EASTGATE 69 - ROSE CYN 69 1 | 50 | | 1.12 | 1.09 | 1.08 | | Will be investigated internally |
| | PENSQTOS 69 - MIRAMRTP 69 1 | 102 | | 1.09 | 1.08 | 1.07 | | Will be investigated internally |
| PENSQTOS - PENSQTOS 1 69/230kV | PENSQTOS 230 - PENSQTOS 69 2 | 269 | | 1.10 | 1.07 | 1.07 | 1.02 | 150% over name plate rating allowed for N-1-1 |

Table 5. **N-1-1 Contingency Analysis for SDG&E (SWPL out-of- service cases)**
**Valley – Rainbow Feasibility Study (Page 2 of 3)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PENSQTOS - PENSQTOS 2 69/230kV | PENSQTOS 230 - PENSQTOS 69 1 | 285 | | 1.03 | | 1.00 | | 150% over name plate rating allowed for N-1-1 |
| MIGUEL - SYCAMORE 1 230.0kV | CARLTHTP 138 - SYCAMORE 138 1 | 204 | | 1.04 | | | | Emergency rating being investigated (1) |
| MISSION - CARLTNHS 1 138.0kV | CARLTHTP 138 - SYCAMORE 138 1 | 204 | | 1.01 | | | | Emergency rating being investigated (1) |
| ESCNDIDO - ESCNDIDO 1 230/ 69kV | ESCNDIDO 69 - ESCNDIDO 230 2 | 261 | | 1.01 | | | | 150% over name plate rating |
| | ESCNDIDO 69 - ESCNDIDO 230 3 | 261 | | 1.01 | | | | Allowed for N-1-1 |
| ESCNDIDO - ESCNDIDO 3 230/ 69kV | ESCNDIDO 69 - ESCNDIDO 230 2 | 261 | | 1.01 | | | | 150% over name plate rating allowed for N-1-1 |
| SYCAMORE - ESCNDIDO 1 230.0kV | ESCNDIDO 69 - ESCNDIDO 230 3 | 261 | | 1.01 | | | | 150% over name plate rating |
| | ESCNDIDO 69 - ESCNDIDO 230 2 | 261 | | 1.01 | | | | allowed for N-1-1 |
| | BERNARDO 69 - FELCTATP 69 1 | 102 | | 1.45 | 1.27 | 1.28 | | Al the following overloads will be investigated internally during SDG&E's annual transmission assessment. |
| | ESCNDIDO 69 - ESCO 69 1 | 102 | | 1.07 | | | | |
| | ESCNDIDO 69 - FELCTATP 69 1 | 102 | | 1.09 | | | | |
| | ESCO 69 - WARCYNTP 69 1 | 102 | | 1.13 | | | | |
| | PENSQTOS 69 - MIRAMRTP 69 1 | 102 | | 1.07 | 1.02 | 1.02 | | |
| | POWAY 69 - WARCYNTP 69 1 | 102 | | 1.08 | | | | |
| | WARNERS 69 - RINCON 69 1 | 32 | | 1.25 | 1.11 | 1.11 | | |
| SYCAMORE 69/230kV #1 or #2 | BERNARDO 69 - FELCTATP 69 1 | 102 | | 1.01 | | | | |
| CREELMAN - SYCAMORE 1 69.0kV | WARNERS 69 - RINCON 69 1 | 32 | | 1.14 | 1.08 | 1.07 | | |
| ES-BE-SF 69.0kV | BERNARDO 69 - FELCTATP 69 1 | 102 | | 1.19 | 1.12 | 1.12 | | |
| ESCNDIDO - ASH 1B 69.0kV | ESCNDIDO 69 - FELCTATP 69 1 | 102 | 1.03 | 1.20 | 1.14 | 1.14 | | |
| | ESCNDIDO 69 - FELICITA 69 1 | 102 | | 1.08 | 1.03 | 1.03 | | |
| ESCNDIDO - ESCO 1 69.0kV | BERNARDO 69 - FELCTATP 69 1 | 102 | | 1.06 | | | | |
| ESCNDIDO - FELICITA 1 69.0kV | ESCNDIDO 69 - FELCTATP 69 1 | 102 | 1.04 | 1.23 | 1.17 | 1.17 | | |
| ESCNDIDO - SANMRCOS 1 69.0kV | MELRSETP 69 - SANLUSRY 69 1 | 102 | | 1.01 | 1.01 | 1.01 | | |
| ESCO - GOALLINE 1 69.0kV | ESCNDIDO 69 - ESCO 69 1 | 102 | | 1.03 | | | | |
| ESCO-PO-WC 69.0kV | BERNARDO 69 - FELCTATP 69 1 | 102 | | 1.06 | | | | |
| FE-AS-VC 69.0kV | ESCNDIDO 69 - LILAC 69 1 | 68 | | 1.03 | | | | |
| GE-PQ-RN 69.0kV | EASTGATE 69 - ROSE CYN 69 1 | 50 | | 1.24 | 1.24 | 1.22 | | |
| | PENSQTOS 69 - MIRAMRTP 69 1 | 102 | | 1.10 | 1.11 | 1.10 | | |

Table 5. **N-1-1 Contingency Analysis for SDG&E (SWPL out-of-service cases)**
**Valley – Rainbow Feasibility Study (Page 3 of 3)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LC-GR-ML 69.0kV | EL CAJON 69 - LOSCOCHS 69 1<br>MURRAY 69 - GARFIELD 69 1 | 55<br>102 | | 1.14<br>1.02 | 1.13<br>1.00 | 1.13 | | Al these overloads will be investigated internally during the annual assessment |
| LL-BAR-DE 69.0kV | WARNERS 69 - RINCON 69 1 | 32 | | 1.02 | | | | |
| MIRAMAR - PENSQTOS 1 69.0kV | PENSQTOS 69 - MIRAMRTP 69 1 | 102 | | 1.05 | 1.05 | 1.05 | | |
| MURRAY - GARFIELD 1 69.0kV | EL CAJON 69 - LOSCOCHS 69 1 | 55 | | 1.06 | 1.05 | 1.04 | | |
| OLD TOWN - KETTNER 1 69.0kV | MURRAY 69 - GARFIELD 69 1 | 102 | | 1.02 | | | | |
| PACFCBCH - OLD TOWN 1 69.0kV | EASTGATE 69 - ROSE CYN 69 1 | 50 | | 1.02 | 1.01 | 1.00 | | |
| PENSQTOS – MESA RIM 1 69.0kV | PENSQTOS 69 - MIRAMRTP 69 1 | 102 | | 1.14 | 1.14 | 1.14 | | |
| POWAY - R.CARMEL 1 69.0kV | BERNARDO 69 - FELCTATP 69 1 | 102 | | 1.04 | | | | |
| SYCAMORE – SCRIPPS 1 69.0kV | PENSQTOS 69 - MIRAMRTP 69 1 | 102 | | 1.06 | 1.05 | 1.05 | | |

Continuous Normal rating used for base case. Continuous Emergency ratings used for outages.

Note: VAR limits had to be opened to achieve convergence in the second SWPL case.

* MVA Rating refers to the rating modeled in the power flow simulations.

(1) An Emergency Rating is being investigated. The planning criteria allows load dropping for the condition; however, a short- or long-term emergency rating would be the preferred solution.

***SCE System Thermal Analysis***

Thermal Analysis, which consists of base case and contingency analysis (N-1, N-2 and N-1-1), was performed. The "all-lines-in-service 80/20 load set of cases" was used for N-1 and N-2 analysis; the "SWPL out-of-service set of cases" was used for N-1-1 analysis. A list of contingencies for the SCE system is shown in Appendix C.

Both sets of cases have an 80/20 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite study.

The objective in studying these cases is to identify the major thermal upgrades required for each alternative.

<u>All-lines in-service cases (SCE Cases)</u>

Base case analysis of the SCE system 'Rainbow alternatives" reveals no thermal problems. In addition, preliminary contingency analysis did not reveal the need for system upgrades in the SCE system.

Table 6 shows a summary of the N-1 contingency analysis for the SCE area. The column labeled "Comments" explains the resolution to most of the overloads.

In the N-1 Table for the Palo Verde – Devers 500 kV outage, the Iron Mountain to Camino 230 kV line loads above the 764.1 Amps normal rating (it does not have an emergency rating) for the Devers – Rainbow and for the Valley – Rainbow alternatives. This line is a segment of an MWD line that runs from Camino to Iron Mountain to Eagle Mountain to Julian Hinds serving the respective pump loads at each location. The Iron Mountain to Eagle Mountain segment has a thermal overload protection Remedial Action Scheme (RAS) set to operate if the line loading from Iron Mountain to Eagle Mountain exceeds 250 MVA. The scheme will open the line from Eagle Mountain to Julian Hinds. This protects the underlying 161 kV system and the Eagle Mountain 230/161 kV transformer.

For the Valley – Rainbow case, the Iron Mountain to Eagle Mountain flow reaches 257.2 MW once the Palo Verde – Devers line is lost. The MWD RAS will operate, and after operation of the scheme no thermal limit violations on MWD's system are observed.

Table 7 shows the results for the N-2 analysis for the SCE system. The column labeled "Comments" explains the resolution to most of the overloads.

SCE system thermal analysis results show :

1. Line loading on Eldorado-Lugo 500 kV line exceeded its long term emergency rating (same of normal rating 1600 Amp.) under the N-1 of Lugo-Victorville 500 kV line and the N-2 of Lugo-Victorville plus one of the Lugo-Vincent 500 kV lines. However, the

line loading was still under its one hour emergency rating, which is 2400 Amp. There are two mitigation plans being developed to solve the problem:

- Plan A – To shift 600 MW path flow from WOR path to Midway-Vincent path and reduce SIL to 3400 MW within one hour.
- Plan B – To upgrade series capacitors to 2100 Amp. normal rating on Eldorado-Lugo 500 kV line.

2. Line loading on Mohave-Lugo 500 kV line was at 100% of its long-term emergency rating, which is same as its 1600 Amp. normal rating. It is going to be the limiting factor of 3600 MW SIL if the overloading problem occurred on the series caps. of Eldorado-Lugo 500 kV line gets solved.

3. Line loading on MWD's Iron Mtn-Eagle Mountain 230 kV line exceeded its 250 MVA thermal limit under the N-1 of Palo Verde-Devers 500 kV line and the N-2 of Lugo-Mira Loma 500 kV lines. The problem triggered MWD's thermal overload RAS to trip Eagle Mtn.-Julian Hinds 230 kV line; the tripping relieves the overloads.

A more detailed analysis that includes the MWD tripping scheme can be found in the Appendix H.

Table 6. **N-1 Contingency Analysis for SCE (all lines in service cases)**
**Valley – Rainbow Feasibility Study**

| Outage | Overloaded Element | MVA Rating | % Loading based on MVA Rating Base | RD | RM | VR | 2sw | Comment |
|---|---|---|---|---|---|---|---|---|
| LUGO - VICTORVL 500 1 | ELDORADO 500 - LUGO 500 1 | 1386 | | 1.07 | 1.11 | 1.09 | 1.01 | Loading on series caps. is under one hour emergency rating. Total 600 MW flow shifting from WOR to Mid.-Vin. path and 200 MW reduction of SIL are needed in 1 hour. |
| | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.06 | | 1.01 | | The N-1 emergency rating should be 2104 MVA. |
| PALOVRDE - DEVERS 500 1 | IRON MTN 230 - CAMINO 230 1 | 304 | | 1.03 | | 1.01 | | MWD existing RAS will be used to solve the problem. |
| SERRANO - VALLEYSC 500 1 | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.15 | | | | The N-1 emergency rating should be 2104 MVA. |
| KRAMER - LUGO 230 1 or 2 | KRAMER 230 - LUGO 230 2 or 1 | 568 | 1.13 | 1.14 | 1.15 | 1.14 | 1.14 | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| IRON MTN - CAMINO 230 1 | EAGLEMTN 230 - EAGLEMTN 161 1 | 77 | 1.31 | 1.45 | 1.38 | 1.42 | 1.35 | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| BIG CRK1 - RECTOR 230 1 | BIG CRK3 230 - RECTOR 230 1 | 373 | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | A detail technical study to evaluate SIL at 2650 MW is needed to address the problem. However, a existing RAS may be applied to solve it. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| BIG CRK3 - RECTOR 230 1 | BIG CRK1 230 - RECTOR 230 1 | 373 | 1.10 | 1.11 | 1.11 | 1.10 | 1.11 | A detail technical study to evaluate SIL at 2650 MW is needed to address the problem. However, a existing RAS may be applied to solve it. |
| EAGLEMTN - IRON MTN 230 1 | EAGLEMTN 230 - EAGLEMTN 161 1 | 77 | 1.19 | 1.34 | 1.26 | 1.30 | 1.22 | The project with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| EL NIDO - CHEVMAIN 230 1 | ELSEGNDO 230 - EL NIDO 230 1 | 951 | 1.03 | 1.03 | 1.04 | 1.03 | 1.03 | Local generation re-dispatch will solve the problem. |
| ELSEGNDO - CHEVMAIN 230 1 | ELSEGNDO 230 - EL NIDO 230 1 | 951 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | Local generation re-dispatch will solve the problem. |
| ELSEGNDO - EL NIDO 230 1 | EL NIDO 230 - CHEVMAIN 230 1 | 951 | 1.03 | 1.03 | 1.04 | 1.03 | 1.03 | Local generation re-dispatch will solve the problem. |

Palo Verde - Devers 500 kV has an Emergency Rating of 2430 Amps / 2104 MVA for N-1 contingencies

Table 7. **N-2 Contingency Analysis for SCE (all lines in service cases)**
**Valley – Rainbow Feasibility Study**

| Outage | Overloaded Element | MVA Rating | % Loading based on MVA Rating | | | | | Comment |
|---|---|---|---|---|---|---|---|---|
| | | | Base | RD | RM | VR | 2sw | |
| LUG - MIR 500 + LUG - ELD 500 | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.03 | | | | The N-1 emergency rating should be 2104 MVA. |
| LUG - MIR 500 + LUG - MIR 500 | IRON MTN 230 - CAMINO 230 1 | 304 | | 1.07 | | 1.05 | | MWD existing RAS will be used to solve the problem. |
| | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.21 | | 1.15 | | The N-1 emergency rating should be 2104 MVA. |
| LUG - MIR 500 + LUG - MOH 500 | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.03 | | | | The N-1 emergency rating should be 2104 MVA. |
| LUG - MIR 500 + LUG - SER 500 | LUGO 500 - MIRALOMA 500 3 | 3934 | 1.01 | 1.10 | 1.15 | 1.12 | 1.05 | The N-2 emergency rating is 5333 MVA. |
| | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.10 | | 1.05 | | The N-1 emergency rating should be 2104 MVA. |
| LUG - MOH 500 + LUG - ELD 500 | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.07 | | 1.01 | | The N-1 emergency rating should be 2104 MVA. |
| LUG - VIC 500 + LUG - VIN 500 | ELDORADO 500 - LUGO 500 1 | 1386 | | 1.08 | 1.13 | 1.11 | 1.03 | Loading on series capacitors is under one hour emergency rating. MW flow shifting from WOR to Mid.-Vin. path and MW reduction of SIL are needed in 1 hour. (numbers still to be determined) |
| | LUGO 500 - MOHAVE 500 1 | 1386 | | | 1.00 | | | same as above |
| | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.07 | | 1.01 | | The N-1 emergency rating should be 2104 MVA. |
| SER - MIR 500 + SER - LUG 500 | PALOVRDE 500 - DEVERS 500 1 | 1646 | | 1.14 | | 1.08 | | The N-1 emergency rating should be 2104 MVA. |
| SPR - BIG 230 + SPR - BIG 230 | BIG CRK1 230 - RECTOR 230 1 | 373 | 1.07 | 1.07 | 1.07 | 1.06 | 1.07 | A detail technical study to evaluate SIL at 2650 MW is needed to address the problem. However, a existing RAS may be applied to solve it. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BIG CRK3 230 - RECTOR 230 1 | 373 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 | A detail technical study to evaluate SIL at 2650 MW is needed to address the problem. However, a existing RAS may be applied to solve it. |
| KRA - LUG 230 + KRA - COL 230 | KRAMER 230 - LUGO 230 1 | 568 | 1.12 | 1.13 | 1.14 | 1.13 | 1.13 | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |

SWPL out-of-service (SCE Cases)

These cases have an 80/20 load for the SDG&E and SCE systems, and heavy summer load for other areas as used by the Cal-ISO in the Composite Study. These cases were studied in order to analyze the system under N-1-1 conditions (an initial N-1, system readjusted, and subsequent N-1). Prior Southern California regional studies have demonstrated that SWPL out of service, followed by any other element presents the most critical condition today. Further assessment was done after adding the new 500 kV line, and results indicated that SWPL initially out of service is the most limiting N-1 event.

Thermal analysis for the SDG&E area have determined that, for SWPL out-of service and system readjusted, the SDG&E imports have to be lowered for the Valley – Rainbow and the Devers Rainbow alternative. In these two alternatives the SDG&E import was lowered to 3400 MW, and the phase shifter was set to control 400 MW of flow in the Valley-Rainbow alternative, and 300 MW in the Devers-Rainbow alternative.

Table 8 on the next page summarizes the results of the SCE contingency analysis for SWPL initially out of service and subsequent outages. The table shows a comparison between the alternatives.

For the Lugo – Victorville outage the Eldorado - Lugo and Mohave - Lugo 500 kV lines are loaded above their continuos emergency rating. The line rating (normal and emergency) for Eldorado - Lugo and Mohave - Lugo 500 kV lines are:

Table 9: El Dorado – Lugo and Mohave – Lugo 500 kV lines ratings

| | **Amperage** | **Duration** |
|---|---|---|
| **Series Cap** | | |
| ➢ Normal Rating | 1600 | Continuous |
| ➢ A Rating (long term Emergency Rating) | 1600 | Continuous |
| ➢ B Rating (One hour rating) | 2400 | One hour |
| **Wave Trap** | | |
| ➢ Normal Rating | 2000 | Continuous |
| ➢ A Rating (long term Emergency Rating) | 2000 | Continuous |
| ➢ B Rating (One hour rating) | 2140 | One hour |

The line loading for these 500 kV lines exceeds long term emergency rating (A Rating) of its series capacitors in the Rainbow option cases. However, the line loadings are under the one-hour emergency rating (B Rating) of the series capacitors. ***This is an N-1-1 situation, and therefore there is time for post-contingency generation redispatch, reduction of SCIT/WOR transfer levels and/or SDG&E import, etc.***

Table 8 in the next page summarizes the results of the SCE contingency analysis for SWPL initially out-of-service and subsequent outages. The table shows a comparison between the alternatives. The following has been identified:

1. Line loading on Barre-Ellis 230 kV line exceeded its 1136 MVA N-1 emergency rating in the N-1-1 base case (pre-project, SIL at 2650 MW) and Rainbow-Valley case. There was a problem identified in the base case at 2650 SIL with all lines in-service. Therefore, a detail technical study is needed to determine SCE system reinforcement to be able to deliver 2650 MW SIL or to determine a load dropping scheme in the SDG&E area to solve the problem within one hour under the N-1-1 system condition to keep the SIL at 2650 MW. It is concluded that the Rainbow-Valley project did not cause this thermal overloading problem.

2. Line loading on Eldorado-Lugo and Mohave-Lugo 500 kV lines exceeded their long term emergency rating of series caps. and wave traps in the N-1-1 base case (SIL at 2650 MW) and Rainbow-Valley case. However, the line loading was still under their one hour short term emergency rating. The problems were not identified in the base case of SIL at 2650 MW with all lines in-service. Therefore, there are two steps needed to address the problems: Step I -- A detail technical study is needed to determine if SCE system reinforcement are needed to deliver 2650 MW SIL and to determine, if needed, a load dropping scheme in the SDG&E area to be activated within one hour under the N-1-1. Step II – To shift path flow from WOR path to Midway-Vincent path and reduce SIL (path flow shifting and SIL reduction numbers are still to be determine) within one hour, or, to upgrade series caps. to 2100 Amp. thermal rating and wave traps to 3000 Amp. thermal rating on Eldorado-Lugo and Mohave-Lugo 500 kV lines.

Table 8. **N-1-1 Contingency Analysis for SCE (SWPL out-of-service cases)**
**Valley – Rainbow Feasibility Study**

| Outage | Overloaded Element | Rating | Loading based on ER Rating | | | | | Comment |
|---|---|---|---|---|---|---|---|---|
| | | MVA | Base | MR | DR | VR | 2sw | |
| BASE CASE | PALOVRDE - DEVERS 500 1 | 1645 | | 0.99 | 1.00 | 0.99 | | Acceptable, sets the import limit |
| MOHAVE - ELDORADO 500 1 | LUGO 500 - MOHAVE 500 1 | 1386 | | 1.00 | 1.00 | 1.00 | | Loading on series caps. is under one hour emergency rating. MW flow shifting from WOR to Mid.-Vin. path and MW reduction of SIL are needed in 1 hour. (numbers still to be determined) |
| PALOVRDE - DEVERS 500 1 | EAGLEMTN 230 - EAGLEMTN 161 1 | 77 | | 1.14 | 1.13 | 1.16 | | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| | IRON MOUNTAIN – CAMINO 230 | 304 | | | | 1.02 | | MWD RAS clears this Overload. |
| | ELDORADO 500 - LUGO 500 1 | 1386 | | | | 1.03 | | Loading on series capacitors is under one hour emergency rating. MW flow shifting from WOR to Mid.-Vin. path and MW reduction of SIL are needed in 1 hour. (numbers still to be determined) |
| BARRE - ELLIS 230 1 | DELAMO 230 - ELLIS 230 1 | 1136 | | 1.01 | | | | This study does not recommend this alternative |
| BIG CRK1 - RECTOR 230 1 | BIG CRK3 230 - RECTOR 230 1 | 373 | 1.18 | 1.18 | 1.18 | 1.18 | 1.18 | A detail technical study to evaluate SIL at 2650 MW is needed to address the problem. However, a existing RAS may be applied to solve it. |
| BIG CRK3 - RECTOR 230 1 | BIG CRK1 230 - RECTOR 230 1 | 373 | 1.11 | 1.11 | 1.11 | 1.10 | 1.11 | A detail technical study to evaluate SIL at 2650 MW is needed to address the problem. However, a existing RAS may be applied to solve it. |
| DELAMO - ELLIS 230 1 | BARRE 230 - ELLIS 230 1 | 1136 | 1.08 | 1.24 | 1.21 | 1.07 | | A detail technical study to evaluate SIL at 2650 MW is needed to address the problem. |
| DEVERS - DEVERS 500/230 1 | MIRAGE 115 - TAMARISK 115 1 | 217 | | 1.00 | 1.01 | 1.02 | | The emergency rating should be 250 MVA. |
| DEVERS - MIRAGE 230 1 | MIRAGE 115 - TAMARISK 115 1 | 217 | | 1.04 | 1.04 | 1.04 | | same as above |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EAGLEMTN - IRON MTN 230 1 | EAGLEMTN 230 - EAGLEMTN 161 1 | 77 | 1.51 | 1.65 | 1.65 | 1.68 | 1.25 | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| EL NIDO - CHEVMAIN 230 1 | ELSEGNDO 230 - EL NIDO 230 1 | 951 | 1.04 | 1.04 | 1.04 | 1.04 | 1.03 | Local generation re-dispatch will solve the problem. |
| ELSEGNDO - CHEVMAIN 230 1 | ELSEGNDO 230 - EL NIDO 230 1 | 951 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | Local generation re-dispatch will solve the problem. |
| ELSEGNDO - EL NIDO 230 1 | EL NIDO 230 - CHEVMAIN 230 1 | 951 | 1.04 | 1.04 | 1.04 | 1.04 | 1.04 | Local generation re-dispatch will solve the problem. |
| IRON MTN - CAMINO 230 1 | BLYTHE 161 - BLYTHESC 161 1 | 187 | | 1.03 | 1.03 | 1.03 | | The emergency rating should be 205 MVA. |
| | EAGLEMTN 230 - EAGLEMTN 161 1 | 77 | 1.62 | 1.77 | 1.77 | 1.79 | 1.36 | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| KRAMER - LUGO 230 1 | KRAMER 230 - LUGO 230 2 | 568 | 1.15 | 1.15 | 1.15 | 1.15 | 1.14 | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| KRAMER - LUGO 230 2 | KRAMER 230 - LUGO 230 1 | 568 | 1.15 | 1.15 | 1.15 | 1.15 | 1.14 | The projects with SIL at 3600 MW caused the line loading increased. A existing RAS will be applied to solve the problem. |
| LUGO - VICTORVL 500 1 | ELDORADO 500 - LUGO 500 1 | 1386 | | 1.23 | 1.25 | 1.31 | 1.03 | Loading on series capacitors is under one hour emergency rating. MW flow shifting from WOR to Mid.-Vin. path and MW reduction of SIL are needed in 1 hour. (numbers still to be determined) |
| | LUGO 500 - MOHAVE 500 1 | 1386 | | 1.07 | 1.08 | 1.12 | | same as above |
| | MIRAGE 115 - TAMARISK 115 1 | 217 | | | | 1.00 | | The emergency rating should be 250 MVA. |
| MIRAGE - MIRAGE 230/115 1 | DEVERS 115 - DEVERS 230 1 | 280 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 | SCE A bank program will address the problem. |
| | DEVERS 115 - DEVERS 230 3 | 280 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | SCE A bank program will address the problem. |

* Continuous Normal rating used for base case. Continuous Emergency ratings used for outages

### *Flowability Analysis*

For the 80/20 load level, flowability analysis was performed for the all-lines-in-service cases. The objective of the analysis was to test the flowability of the new line absent the phase shifters. In addition, line compensation in the 230 kV lines out of Rainbow Substation was explored.

Table 10 summarizes a flowability analysis. It shows the flowability of the line for the different Rainbow" Alternatives" absent the phase shifters and the flowability absent the phase shifters and with 70% compensation in the 230 kV lines out of Rainbow and into the SDG&E system. The flowability absent the phase shifters with or without the compensation is around 500 MW. This is 50 % of the proposed 1000 MW rating for the line.

Table 10

**Flowability Analysis**

| | With Phase Shifters | Without Phase Shifters | Without Phase Shifters + 70% Compensation in 230 kV lines |
|---|---|---|---|
| Valley-Rainbow @ 3600 MW of import into San Diego | 1003 MW | 470 MW | 500 MW |
| Devers-Rainbow @ 3600 MW of import into San Diego | 1003 MW | 439 MW | 457 MW |
| Mira Loma - Rainbow @ 3600 MW of import into San Diego | 1002 MW | 549 MW | 577 MW |

### *Incremental Losses Analysis*

Incremental loss analysis was performed for the all-lines-in-service 80/20 load cases. The incremental losses presented represent the increase in losses between the post-Project and the pre-Project case.

Base case analysis of the losses for the different alternatives is summarized in Table 11. In the SDG&E system the incremental real power losses (post-project minus pre-project) are comparable and the MVAR losses are higher by roughly 100 MVAR for the second SWPL alternative. In the SCE system, the incremental real power losses are highest for the Devers – Rainbow alternative at 62 MW. This can be compared to 57 MW for the Valley – Rainbow alternative, 48 MW for the Mira Loma – Rainbow alternative and 18 MW for the second SWPL alternative. The reactive power losses for the SCE system range from 1029 MVAR for the Valley – Rainbow alternative to 369 MVAR for the second SWPL alternative.

Table 11

## Incremental Losses

| | Valley- Pala/Rainbow Alternative | Devers - Pala/Rainbow Alternative | Mira Loma - Pala/Rainbow Alternative | Second SWPL Alternative |
|---|---|---|---|---|
| **SDG&E Real Power Losses** | 28 MW | 29 MW | 29 MW | 31 MW |
| **SDG&E Real Power Losses** | 409 MVAR | 413 MVAR | 415 MVAR | 457 MVAR |
| **SCE Real Power Losses** | 57 MW | 62 MW | 48 MW | 18 MW |
| **SCE Reactive Power Losses** | 1029 MVAR | 939 MVAR | 725 MVAR | 369 MVAR |

### *G-1 (Encina 5 out-of-service initially), N-1 (SWPL outage)*

This preliminary study was only performed for the Valley-Rainbow alternative. The case without Encina 5 shows no overloads and an acceptable voltage profile. Imports into the SDG&E system are at 3600 MW in the G-1 case.

Selected bulk power contingencies where run to validate the case and to find the worst next contingency. The two worst contingencies found are the Valley-Rainbow 500 kV line and the Imperial Valley – Miguel 500 kV with the subsequent tripping of Imperial Valley – Tijuana 230 kV line.

After the Valley-Rainbow contingency, the Palo Verde – North Gila 500 kV line loads to 103% the series capacitors continuos rating, but it is well under the emergency rating. If this loading is to be brought down within the continuos rating, the San Diego imports have to be reduced by approximately 100 MW and generation in the South Bay area should be brought up.

After the Imperial Valley – Miguel 500 kV outage with the subsequent tripping of Imperial Valley – Tijuana 230 kV line, the SDG&E imports have to be brought down to 3400 MW and the flow in the Rainbow – Valley line has to be controlled to around 400 MW if the Palo Verde – Devers line is to be brought to a loading level within its continuos rating.

Appendix J shows printouts summarizing the case where Encina 5 is out of service initially and subsequent SWPL outage.

***Post-transient Studies***

Post-transient studies were performed to determine voltage deviation and voltage magnitude for the following critical contingencies:

1. Around the Valley 500 kV Substation
   - N-1 of Serrano-Valley 500 kV
   - N-1 of Devers-Valley 500 kV
   - N-1 of Rainbow-Valley 500 kV
   - N-2 of Rainbow-Valley and Serrano-Valley 500

2. SCE 500 kV path to deliver SIL 3600 MW
   - N-1 of Lugo-Serrano 500 kV
   - N-1 of Lugo-Mohave 500 kV
   - N-1 of Lugo-Victorville 500 kV
   - N-2 of Lugo-Mira Loma 500 kV
   - N-2 of Lugo-Victorville and Lugo-Vincent 500 kV
   - N-2 of Lugo-Vincent 1&2 500 kV

3. SCE Orange County Area
   - N-2 of Ellis-Johanna and Ellis-Santiago 230 kV

4. In the SDG&E area
   - N-1 of Imperial – Valley to Miguel 500 kV with the cross-tripping of the Miguel – Tijuana 230 kV in the SDG&E system.

Table 12 shows a summary of the results. It indicates that the Victor 230 kV bus in the SCE system has a voltage outside the monitor range but within the acceptable range. The post-outage voltages will be studied in more detail during Phase 2 after the refinement of the SDG&E capacitor switching scheme; this refinement is expected to further support the post-outage voltage profile. All runs were within the acceptable voltage deviation.

Table 12. Post-Transient Analysis

**80/20 LOAD, TWO SONGS, ALL LINES IN-SERVICE CASES**

| Outage | BENCHMARK CASE<br>Voltages in SCE outside monitored range | VALLEY-RAINBOW CASE<br>Voltages in SCE outside monitored range | Acceptable voltage Range post-outages | Voltage Violations |
|---|---|---|---|---|
| Imperial V. - Miguel 500 kV<br>Miguel - Tijuana 230 kV | Victor 230 kV at 221.7 kV | Victor 230 kV at 218.2 kV | 213.0 kV - 248.0 kV | None |
| Lugo - Serrano 500 kV | Victor 230 kV at 223.8 kV | Victor 230 kV at 221.1 kV | 213.0 kV - 248.0 kV | None |
| Lugo - Mohave 500 kV | Victor 230 kV at 223.4 kV | Victor 230 kV at 220.4 kV | 213.0 kV - 248.0 kV | None |
| Lugo - Victorville 500 kV | Victor 230 kV at 222.4 kV | Victor 230 kV at 220.0 kV | 213.0 kV - 248.0 kV | None |
| Serrano - Valley 500 kV | Failed to solve | Victor 230 kV at 223.3 kV | 213.0 kV - 248.0 kV | None |
| Devers - Valley 500 kV | None | Victor 230 kV at 220.9 kV | 213.0 kV - 248.0 kV | None |
| Rainbow - Valley 500 kV | N/A | Victor 230 kV at 222.7 kV | 213.0 kV - 248.0 kV | None |
| Rainbow - Valley 500 kV<br>+ Serrano - Valley 500 kV | N/A | Victor 230 kV at 223.0 kV | 213.0 kV - 248.0 kV | None |
| Lugo - Mira Loma 500 kV 2&3 | Victor 230 kV at 220.7 kV | Victor 230 kV at 217.2 kV | 213.0 kV - 248.0 kV | None |
| Lugo - Victorville 500 kV<br>+ Lugo - Vincent 500 kV | Victor 230 kV at 220.9 kV | Victor 230 kV at 218.3 kV | 213.0 kV - 248.0 kV | None |
| Lugo - Vincent 500 kV 1&2 | Victor 230 kV at 222.9 kV | Victor 230 kV at 219.9 kV | 213.0 kV - 248.0 kV | None |
| Ellis - Johanna 230 kV<br>+ Ellis - Santiago 230 kV | Santiago 230 kV at 216.9 kV | Victor 230 kV at 222.0 kV<br>Santiago 230 kV at 216.4 kV | 213.0 kV - 248.0 kV<br>208.0 kV - 236.0 kV | None |

### *SCE Short Circuit Duty (SCD) Study Results*

Table 13 summarizes SCE SCD study results for the three " Rainbow Alternatives". Short circuit studies have not been performed for the second SWPL alternative, since that alternative is not expected to increase the SCD in the SCE system. Studies may be performed at a later date for the second SWPL if that alternative were to be pursued. Short circuit duty results show that the actual duty measured at the three locations increases in post-project cases. However, the duties did not exceed the circuit breaker (CB) rating.

The SCD at Devers 500 kV, 230 kV and 115 kV, and at Mira Loma 500 kV and 230 kV increased for the three alternatives. The actual SCD GVA at Devers 230 kV and 115 kV and Mira Loma 230 kV are above 80% of the existing rating for the Devers - Rainbow and Mira Loma - Rainbow alternatives. No CB overstressing problems have been identified at Valley 500 kV or 115 kV based on the study assumptions. SCE CBs with loading greater than 80% require an engineering evaluation to determine the breaker specific allowable overstressing capability based on the SCE planning criteria.

Table 13. Short Circuit Performance

| | **Valley-Rainbow** | **Devers-Rainbow** | **Mira Loma-Rainbow** |
|---|---|---|---|
| Critical breakers | @Valley 500/115 kV | @Devers 500/230 kV | @Mira Loma 500/230 kV |
| Actual Value | 11.8/4 GVA | 11.1/9.1*GVA | 26.3/23.1* GVA |
| Ratings | 35/8 GVA | 35/10 GVA | 35/25 GVA |
| Preproject /postproject difference | 1.6/.8 GVA | 1.3/.3 GVA | 1.0/.3 GVA |

* Over 80% of current CB rating.

## ***Transient Stability Analysis***

The transient stability analysis was performed for the all-lines-in-service case at the 80/20 load level. Eight major "Level A" disturbances, as defined by the WSCC Criteria, were evaluated for the four alternatives. The transient stability analysis was performed by GE Power Systems Energy Consultants.

The following fault scenarios were evaluated on all four interconnection alternatives:

- Palo Verde-N. Gila 500 kV line (3-phase fault at Palo Verde)
- Palo Verde-Devers 500 kV line (3-phase fault at Palo Verde)
- Navajo-Crystal Lake 500 kV line (3-phase fault at Navajo)
- Moenkopi-Eldorado 500 kV line (3-phase fault at Moenkopi)
- Imperial Valley-Miguel 500 kV line (3-phase fault at Imperial Valley, with subsequent tripping of Miguel – Tijuana 230 kV line if appropriate)
- Lugo–Mira Loma 2&3 500 kV lines (3-phase fault at Lugo)
- Serrano–Valley 500 kV line (3-phase fault at Valley)
- Devers–Valley 500 kV line (3-phase fault at Devers)
- Rainbow-Devers 500 kV line (3-phase fault at Rainbow)
- Rainbow-Mira Loma 500 kV line (3-phase fault at Rainbow)
- Rainbow-Valley 500 kV line (3-phase fault at Rainbow)
- Palo Verde-Imperial Valley #2 500 kV line (3-phase fault at Palo Verde)

The switching files can be found in Appendix E of the GE report, which can be found in Appendix E of this report.

All fault disturbances for all interconnection alternatives met the WSCC criteria.

A more detailed discussion and detailed plots of the stability analysis results are included in Appendix F of the GE Report, and in the report itself.

### *Voltage Stability Analysis*

The basic study approach involved evaluating the relative project performance for the four interconnection projects, based on a 50/50 load forecast level. Both P-V/V-Q analysis were performed. Although V-Q analysis was performed for all alternatives, the P-V analysis was performed only for the preferred alternative. The voltage stability analysis was performed by GE Power Systems Energy Consultants. A detailed description of the analysis can be found in the GE Report in Appendix E.

The most critical “G-1/N-1” contingency conditions (which the Cal-ISO expects to meet single-contingency standards) for evaluation of voltage stability are loss of one SONGS unit (with system readjusted) followed by loss of one of the following lines:

- Imperial Valley - Miguel 500 kV Line (and subsequent tripping of the Miguel – Tijuana 230 kV Line, if appropriate);
- Valley - Rainbow 500 kV Line or other alternative 500 kV line such as Devers – Rainbow or Mira Loma – Rainbow;
- Serrano – Valley 500 kV Line;
- Devers – Valley 500 kV Line; or
- Palo Verde – Devers 500 kV Line.

The most critical double contingency conditions for evaluation of voltage stability are loss of one of the following elements:

- Two San Onofre units;
- Ellis – Johanna and Ellis – Santiago 230 kV Lines;
- Lugo – Mira Loma 2 & 3 500 kV Lines; or
- SWPL #1 and #2 500 kV Lines.

All of the alternatives show a need for additional reactive support in the SDG&E area. Reactive power margin studies show deficiencies in the SDG&E system of around 1000 MVars for all the alternatives. Based on Var margin violations, the following tentative measures for voltage support were studied:

- Placed in-service the Encina 1 14.4 kV and South Bay 20.0 kV units at 50 MW each and dispatched among the existing neighboring generator units.
- Switched in the existing 69.3 MVar shunt capacitor at Penasquitos and Escondido 230 kV buses. (The Rainbow-Valley alternative case already had the Escondido 230 kV shunt capacitor in-service).
- Switched in a second 100 MVar shunt capacitor at Rainbow 500 kV bus.

- Switched in 200 MVar shunt capacitor at San Luis Ray 230 kV bus.
- Switched in 200 MVar shunt capacitor at Sycamore Canyon 230 kV bus.
- Switched in 100 MVar shunt capacitor at Penasquitos 69 kV bus.
- Switched in 100 MVar shunt capacitor at Escondido 230 kV bus.
- Switched in 100 MVar shunt capacitor at Mission 230 kV bus.

As stated previously, a review of the GE study results indicates that all the alternatives require about 1000 MVAR of reactive power support, with at least 30% of it being dynamic. The GE study results are being used for the purpose of comparing the alternatives. Final detailed design of the reactive power support requirements will be conducted by SDG&E for the preferred alternative as the design details are further refined. SDG&E is in the process of conducting additional studies to fine-tune the reactive power requirements for the preferred alternative and determine the required mixture of static and dynamic reactive power support.

***Evaluation of FACTS***

Preliminary evaluation of the ability of a FACTS device (for example, a Unified Power flow Controller or “UPFC”) to serve as an alternative to the Rainbow phase-shifting transformer has been performed, and is documented in the GE final report.

A preliminary review of the study results conducted by GE indicate that a 150-300 MVA UPFC installed at Rainbow Substation will be required to control the flow on the Rainbow – Valley 500 kV line to 1000 MW during base case and Imperial Valley – Miguel 500 kV and Miguel – Tijuana 230 kV lines outage conditions. SDG&E needs to conduct additional sensitivity studies to determine the final sizing of the UPFC. The GE study results indicate that the cases with UPFC reduce the need for additional reactive power support by about 453.5 MVARs as compared with the PAR cases. SDG&E is in the process of reviewing GE transient stability results. A preliminary review of the results indicate that cases with UPFC result in significant improvement in transient voltage dip and damping of oscillations as compared with the cases with the phase shifter.

UPFC design characteristics will be determined based on the desired pre-contingency loading of the Valley – Rainbow 500 kV line. The UPFC – if this is the selected option – is proposed to be sized to control the flow on this line to 1000 MW during steady state pre-contingency periods. SDG&E will conduct further studies to determine the final sizing of the shunt and series element of the UPFC. The series element of the

UPFC will be sized to control the pre-contingency flow on the Valley – Rainbow 500 kV line to 1000 MW. The shunt element of the UPFC will be sized to control the Rainbow 500 kV voltage to 1.0 P.U. during pre and post-contingency loss of Imperial Valley – Miguel 500 kV and Miguel – Tijuana 230 kV lines.

GE has provided SDG&E with beta models for the UPFC. The GE models for the UPFC are not commercial grade models supported by PSEC's PSLF group, but rather beta models requiring additional testing before inclusion in an official version of PSLF. The GE model does not directly control the amount of reactive power injected by the series converter. The amount of injected reactive power is controlled by setting the magnitude of the injected voltage. The GE model does, however, directly control the injection of real power into the line. SDG&E needs to conduct additional sensitivity studies varying the amount of injected reactive power by the series converter to determine the fine tune the sizing of the UPFC

In summary, the UPFC will:

- **Provide dynamic reactive power support and voltage control at Rainbow**

  The UPFC provides dynamic reactive power support almost instantaneously without the use of shunt capacitors. The UPFC can continuously adjust the Rainbow/Pala bus voltage at the desired settings without loss of power quality

- **Eliminate the need for the phase shifting transformer at Rainbow**

  The UPFC is capable of regulating the power flow on the Rainbow – Valley 500 kV line almost instantaneously without the use of phase shifters.

- **Improve system stability in the WSCC system**

  The UPFC provides dynamic reactive power support at Rainbow which can be utilized during critical contingency conditions improving system damping and reducing transient voltage dips. This could prevent system breakup during critical contingencies and reduces oscillations for all system disturbances

- **Improve Power Quality**

  The UPFC provides bumpless voltage control without switching capacitor or reactor banks. The UPFC will automatically compensate for load changes, nearby capacitor switching, and tap changer operations

- **Minimize the Potential for Voltage Collapse**

  The UPFC minimizes the potential for a system blackout by providing dynamic reactive power support almost instantaneously

- **Control real and reactive power flow on Rainbow/Pala – Valley 500 kV line**

  The UPFC can simultaneously, almost instantaneously, and independently control the real and reactive power flow during steady state and almost instantaneously following a contingency. A phase shifter will require about 5-15 minutes to control the flow following a contingency

- **Mitigate potential Sub-Synchronous Resonance problems**

  The UPFC can control the flow without insertion of series capacitors and therefore mitigates any sub-synchronous resonance concerns

As part of WSCC Phase 2 studies SDG&E will need to do the following:

1) thoroughly review the GE study results for the case with UPFC
2) evaluate the GE UPFC model
3) determine the final sizing of the UPFC
4) thoroughly review the technical aspects of a UPFC and a phase shifter
5) evaluate the economics of installing a phase shifter versus a UPFC

# Appendix A

General information about the cases

# Appendix B

Printouts for the cases

# Appendix C

One Line Diagrams for the cases

# Appendix D

Contingency list for SDG&E and SCE

# Appendix E

GE Study Report

# Appendix F

GE UPFC Study Report

# Appendix G

## Project Cost Estimates

The following table indicates the relative costs of each alternative, including the preferred alternative, on a per unit (P.U.) basis based on the estimated cost of the Valley – Rainbow alternative. For example, the midpoint of the estimated range of cost of the Valley – Rainbow proposal is assigned a value of 1.00 Per Unit. Due to right-of-way uncertainties and other variables, the range of costs for the Valley – Rainbow proposal may be from 0.81 to 1.19 of that per unitized midpoint value. For comparison, the midpoint of the Devers – Rainbow cost is 1.43 times the midpoint of the Valley – Rainbow cost, with a range anywhere from 20% to 66% more expensive than the Valley – Rainbow proposal.

Actual cost estimates are not provided in order to preserve the competitive bidding process.

| Alternative | Estimated P.U. Cost | Possible Range of P.U. Cost | |
|---|---|---|---|
| | (Midpoint) | (Low End of Range) | (High End of Range) |
| | | | |
| Valley - Rainbow | 1.00 | 0.81 | 1.19 |
| Devers – Rainbow | 1.43 | 1.20 | 1.66 |
| Mira Loma – Rainbow | 1.58 | 1.33 | 1.82 |
| Second SWPL | 2.58 | 2.32 | 2.84 |

# Appendix H

MWD Analysis

# Appendix I

Post-Transient Analysis

# Appendix J

G-1 Encina 5, N-1 SWPL Printouts