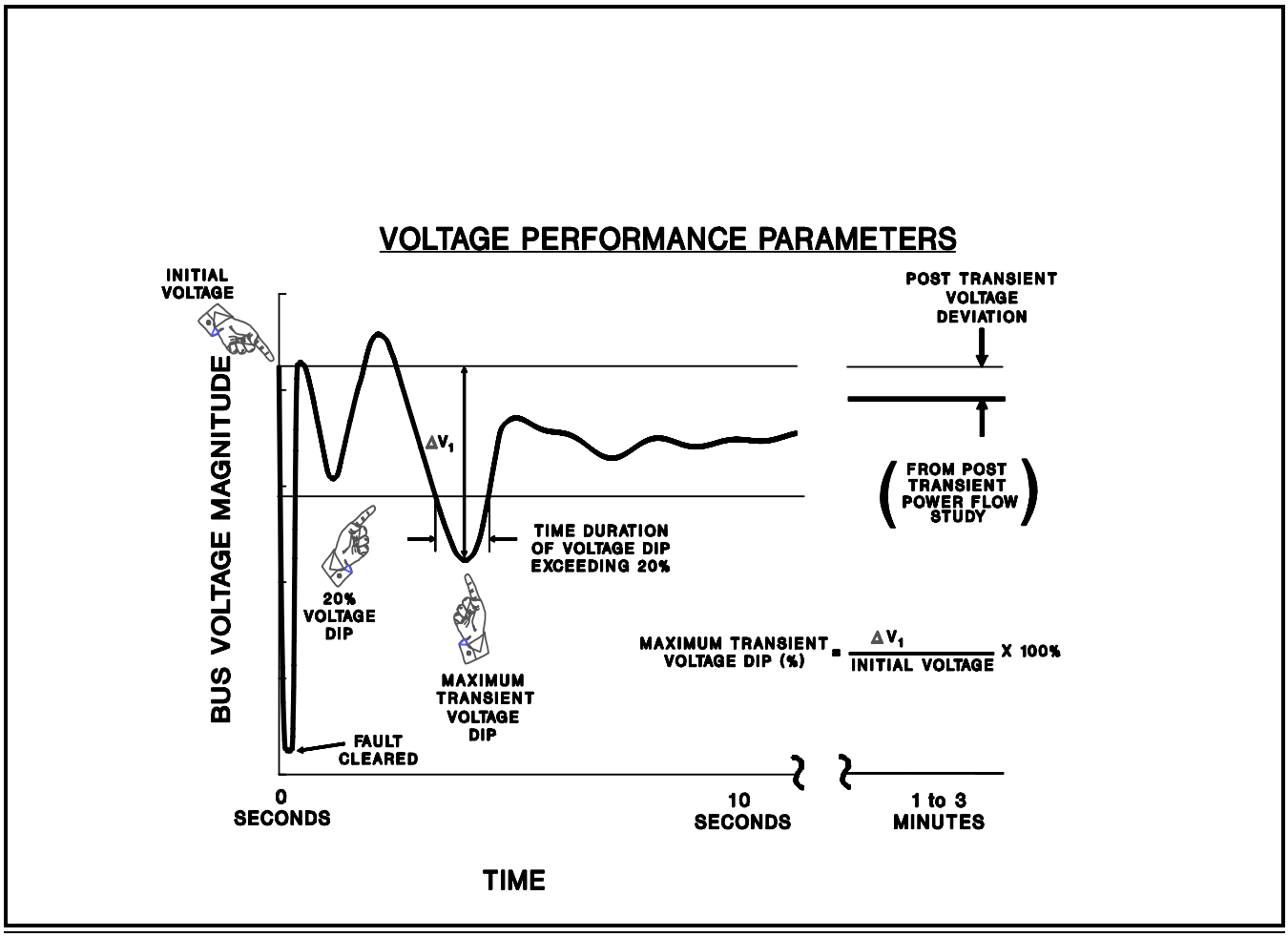
## 1. STUDY METHODOLOGY

Dynamic stability studies were performed for the selected alternatives of the STEP Project to determine if the system performance satisfies the NERC/WECC criteria. Transient stability performance criteria are included in the WECC Standards. They are briefly summarized in the following table.

**WECC DISTURBANCE-PERFORMANCE TABLE**
**OF ALLOWABLE EFFECTS ON OTHER SYSTEMS**

| NERC and WECC Categories | Outage Frequency Associated with the Performance Category (outage/year) | Transient Voltage Dip Standard | Minimum Transient Frequency Standard | Post Transient Voltage Deviation Standard (See Note 2) |
|---|---|---|---|---|
| A | Not Applicable | Nothing in addition to NERC | | |
| B | ≥ 0.33 | Not to exceed **25%** at load buses or **30%** at non-load buses.<br><br>Not to exceed **20% for more than 20 cycles** at load buses. | Not below **59.6** Hz for 6 cycles or more at a load bus. | Not to exceed **5%** at any bus. |
| C | 0.033 – 0.33 | Not to exceed **30%** at any bus.<br><br>Not to exceed **20% for more than 40 cycles** at load buses. | Not below **59.0** Hz for 6 cycles or more at a load bus. | Not to exceed **10%** at any bus. |
| D | < 0.033 | Nothing in addition to NERC | | |

The voltage performance criteria are illustrated in the following plot.




The studies investigated, which alternative is preferred from the dynamic stability perspective and what additional reactive support is required for each alternative to satisfy the criteria. Peak and off-peak system conditions were studied.

All single and double 500 kV outages in the Southwest were studied for each alternative. Each contingency was modeled as a four-cycle, three-phase fault on the sending end of the transmission line cleared by the opening of the line. The system performance during single outages was compared with the standards for the Category B contingencies, and the performance during double outages was compared with the standards for the Category C contingencies.

The system dynamic stability performance was studied using GE PSLF computer program and a computer routine developed by the Cal-ISO, which runs dynamic simulations according to the list of contingencies using files with switching sequences for these contingencies. The program analyzed the output for each contingency, determined and listed the critical buses with the highest voltage dip and lowest frequency, compared the system performance with the WECC criteria and listed all voltage and frequency criteria violations if any.

### *3.2. Short-term Upgrades*

Dynamic stability studies were performed for the STEP Project short-term upgrades. These upgrades include thermal upgrades of the series capacitors on SWPL, Palo Verde-Devers, Navajo-Crystal and Moenkopi-Eldorado 500 kV transmission lines and installation of the second 500/230 kV transformer at Devers Substation. Second Miguel 500/230 kV transformer was also modeled as a part of the SDG&E upgrades.

The details of these studies are provided in Attachment III.

The power flow case studies modeled 8300 MW East-of-River flow and off-peak loading conditions, since the off-peak conditions have higher flows on 500 kV lines and higher East-of-River flow and therefore are more critical. Initially, the case modeled 400 MVAR SVC at the Devers 500 kV bus and no other dynamic reactive support.

As can be seen from Attachment III, majority of the contingencies did not show any criteria violations, except for the Palo Verde-Devers and Hassyampa-North Gila outages. Several contingencies, such as Lugo-Eldorado, Lugo-Mohave and Lugo-Vincent Nos.1 and 2 double outages, and Lugo-Victorville single outage had delayed voltage recovery after the fault. Three-phase faults on the Valley 500 kV bus showed unacceptable frequency dip on the Valley 115 kV load bus with the fault, the same as was identified in the initial studies of STEP Project alternatives and the Alternative AC 1. This may be a modeling error in modeling Valley 500/115 kV transformers, SCE is investigating this problem.

Palo Verde-Devers outage caused frequency violations on three generator buses in the Midway area of the Imperial Irrigation District (IID). Hassyampa-North Gila outage caused numerous voltage criteria violations in the SCE, Nevada and LADWP areas. The highest voltage dip (27%) was observed on the Wilmington 138 kV load bus in LADWP. All these violations are shown in the tables and the plots in Attachment III.

Studies were performed to identify amount and location of reactive support to eliminate the voltage violations. However, additional reactive support did not eliminate frequency violations for the Palo Verde-Devers outage. To mitigate these violations, either East-of-River flow need to be decreased, or generators, which cause violations, tripped with this outage. These generators are Del Ranch, Jjelmore and Leathers, 45 MW each. Addition of the second 500 kV line from Palo Verde to Devers (Harquahala-Devers) will also eliminate this problem.

The studies determined that in order to avoid voltage violations with the Hassyampa-North Gila outage, required dynamic reactive support should include 400 MVAR Statcon at the Devers 500 kV bus and either 300 MVAR Statcon at the Devers 115 kV bus or 400 MVAR SVC at the Valley 500 kV bus.

The base case modeled 600 MW of Monte Vista generation. These are old units, which may be retired in the nearest future. Sensitivity studies were performed for the case without the Monte Vista generation and the same 8300 MW EOR flow. 400 MVAR Statcon was modeled at the Devers 500 kV bus and 400 MVAR SVC at the Valley 500 kV bus. These studies showed voltage criteria violations with the Hassyampa-North Gila outage and frequency violations with the Palo Verde-Devers outage. When the SVC at the Valley bus was replaced by the same size Statcon, the Hassyampa-North Gila outage did not show any violations. The results of these studies, including plots comparing performance of SVC and Statcon, are also in Attachment III.

Next sensitivity study assumed new generation plants Otay Mesa and Palomar in San Diego and Mountain View in SCE being in service. This generation displaced old inefficient generation in SCE and SDG&E (Encina, South Bay, Alamitos 3, Huntington Beach, Redondo Beach, El Segundo). The studies were performed to identify dynamic reactive support required in this case. Without any additional dynamic reactive support, the studies showed both voltage and frequency violations for the Palo Verde-Devers outage, and no criteria violations for the Hassyampa-North Gila outage. Installation of a 400 MVAR Statcon on the Valley 500 kV bus eliminated voltage, but not frequency violations for the Palo Verde-Devers outage. The same size Statcon at Devers 500 kV, significantly reduced, but not eliminated all voltage violations.

It can be concluded that generation additions in Southern California (especially, Mountain View generation in SCE) significantly improve voltage dynamic stability performance and allow installation of fewer dynamic reactive support than without these generation additions. However, this generation did not help for the frequency violations with the Palo Verde-Devers outage.

Next sensitivity study was performed for the same case with the new generation additions, but in assumption that the Perkins and Liberty phase shifters are bypassed, since it is how the system is normally operated. East-of-River flow was modeled at the same, 8300 MW, level. In this case, the flow on the Palo Verde-Devers and Hassyampa-North Gila 500 kV lines was approximately 200 MW higher than when the phase shifters are utilized. Palo Verde-Devers and Hassyampa-North Gila outages were studied, since these outages are the most critical. The studies without additional reactive support showed numerous voltage and frequency violations for both contingencies.

Addition of 400 MVAR Statcon at the Devers 500 kV bus and 400 MVAR Statcon at the Valley 500 kV bus, reduced, but not eliminated all the violations. The Palo

Verde-Devers outage appeared to be more severe than the Hassyampa-North Gila outage.

The study determined that with the Perkins and Liberty phase-shifters bypassed and 400 MVAR Statcons at Devers and Valley, East-of-River flow should not exceed 8200 MW, to avoid voltage dynamic stability criteria violations (frequency violations on three IID buses with the Palo Verde-Devers outage remain at this flow level).

To eliminate frequency violations with the Palo Verde-Devers outage, the EOR flow need to be reduced to 7650 MW if the Perkins and Liberty phase shifters are bypassed, and to 7860 MW if these phase shifters are in operation, maintaining 1250-1270 MW flow on the Perkins-Mead 500 KV line and 480-495 MW flow on the Liberty-Peacock 345 kV line.

The results of these studies, including dynamic stability plots are shown in Attachment III.

It can be concluded that bypassing Perkins and Liberty Phase shifters aggravates dynamic stability performance, and therefore, if the East-of-River flow is high, these phase shifters should be in operation.

### 3.2.1. Studies of the East-of-River Limits

All previously performed East-of-River (EOR) Path rating studies used “7% flow margin” criteria for this path. These criteria were imposed by the Navajo, Palo Verde and Mead-Phoenix transmission system owners and were a part of the operation of the EOR Path for over twenty years. The criteria states that to establish certain EOR flow limit, the system has to satisfy WECC performance criteria for the EOR flow at 7% above this limit. The intent of having such a margin is to ensure that the system remains stable and within all the criteria during unforeseen events.

The studies show that if the EOR flow is increased 7% (for the short-term upgrade case from 8300 MW to 8880 MW), significant additional reactive support will be required to avoid voltage violations. Addition of six Statcons: 1000 MVAR at Devers 500 kV, 300 MVAR at Devers 115 kV, 500 MVAR at Valley 500 KV, 400 MVAR at Adelanto 500 kV, 200 MVAR at Victorville 287 kV and 200 MVAR at Needles 138 kV (total 2600 MVAR) will eliminate all voltage violations, but not frequency violations with the Palo Verde-Devers outage.

The studies were also performed to determine what the EOR flow limit would be depending on different level of dynamic reactive compensation. The power flow case with short-term STEP Project upgrades was studied. Different assumptions regarding operations of the Perkins and Liberty phase shifters and regarding new Otay Mesa, Palomar and Mountain View generation were used.

The detailed study results are provided in the Attachment IV. The limiting factor appeared to be frequency violations on the three IID buses with the Palo Verde-Devers 500 kV line outage. To avoid theses violations, the EOR flow needs to be substantially reduced.

The results for all the cases studies are summarized in the following table.

| PERKINS AND LIBERTY PH. SHIFTERS | OTAY MESA, PALOMAR, MNT VIEW GENERATION | DYNAMIC REACTIVE SUPPORT | FREQUENCY VIOLATIONS IN IID | EOR FLOW |
|---|---|---|---|---|
| IN SERVICE | NO | 400 MVAR STATCON DEVERS AND VALLEY 500 KV | YES | 8300 MW |
| IN SERVICE | NO | 400 MVAR STATCON DEVERS AND VALLEY 500 KV | NO | 8170 MW |
| IN SERVICE | YES | 400 MVAR STATCON DEVERS AND VALLEY 500 KV | NO | 7860 MW |
| IN SERVICE | YES | 400 MVAR STATCON DEVERS | YES | 8210 MW |
| IN SERVICE | YES | 400 MVAR STATCON VALLEY | YES | 8300 MW |
| BYPASSED | NO | 400 MVAR STATCON DEVERS AND VALLEY 500 KV | YES | 8150 MW |
| BYPASSED | NO | 400 MVAR STATCON DEVERS AND VALLEY 500 KV | NO | 7860 MW |
| BYPASSED | YES | 400 MVAR STATCON DEVERS AND VALLEY 500 KV | YES | 8200 MW |
| BYPASSED | YES | 400 MVAR STATCON DEVERS AND VALLEY 500 KV | NO | 7650 MW |

As can be seen from the table, if the “7% margin” criteria are applied, the EOR path rating should not exceed 7150 MW in assumption of new generation replacing the inefficient units and Liberty and Perkins phase shifters bypassed. This rating is lower than the present 7550 MW rating.

If these violations are ignored (or generation tripping allowed for this outage), the EOR rating will depend on amount of dynamic reactive support. With a 400 MVAR Statcon at Valley or Devers and new generation in SDG&E and SCE, the EOR rating may be as high as 7760 MW. To allow higher EOR rating, the Perkins and Liberty phase shifters should be in service at high EOR flow.

The lower EOR limit compared to the accepted 7550 MW rating can be explained by lower generation in SCE and SDG&E, since in the studies, it was assumed that new generation plants in Arizona replace old inefficient generation in Southern California. Due to the large amount of dynamic reactive support required to maintain EOR rating, such replacement may appear not economical.