Generator Interconnection System Impact Study

For [redacted] Generator at Station 21

Revision 1

Prepared for:

[redacted]

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SCE&G Transmission Planning

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1. Introduction

A Generator Interconnection System Impact Study is normally performed after the Generation Interconnection Feasibility Study. For this request, Transmission Planning and the customer agreed to forgo the Generator Interconnection Feasibility Study.

The Generator Interconnection System Impact Study identifies any thermal overload or voltage limit violations, any circuit breaker short circuit capability limits and any instability or inadequately damped response to system disturbances resulting from the interconnection. It also provides a non-binding, good faith estimate of the costs of the facilities required to interconnect the Generator to the Transmission System and to address any identified power flow, short circuit and instability issues.

2. General Discussion

In this study, [redacted] requested interconnection at the 13.8kV load bus of Station 21 on the [redacted] site. This generator would be connected to the 13.8kV side of a 115-13.8kV delta-wye transformer. A discussion of the effects of this type of generator interconnection is included in Section 7 - Required Interconnection Facilities and Estimated Cost.

The proposed generator has a maximum net output of 18 MW. Commissioning of the Plant will start June 2011 with Commercial Operation by December 15, 2011.

3. Generator Information

The gas turbine generator manufacturer's design data used in this study are included in the Appendix.

4. Steady State Contingency Analyses

4.1. Power Flow Model Assumptions

Transmission Planning performed steady state contingency analysis for the 2012 summer peak load conditions. Analyses were performed with and without the existing Station 44 generators. There are several assumptions made in these steady state analyses. Those assumptions are:

1. Stations 11, 12, 64 and 66 are retired and the 115kV line between Stations 52 and 53 serving these stations is not in service.
2. Existing generation at Station 44 will be available during the commissioning stage starting in June 2011 until the start of commercial operation in December 2011, after which it will be decommissioned.
3. No significant network improvements are planned in the [redacted] Area in the foreseeable future.
4. Loading in the [redacted] area will remain constant in the foreseeable future.

4.2. 2012 Summer Peak Contingency Analysis Results

The reported results below include analyses both with and without Station 44 units generating. For both analyses the conclusions were the same.

4.2.1. N-0 (Base case) Results

No overloaded facilities, highly loaded facilities or voltages out of range were identified in the 2012 summer peak basecase due to the addition of the proposed unit at [redacted] Station 21.

4.2.2. N-1 Results

Single contingency analyses identified no overloaded facilities, highly loaded facilities or voltages out of range due to the addition of the proposed unit at [redacted] Station 21.

4.2.3. N-2 Results

Double contingency analyses identified no overloaded facilities, highly loaded facilities or voltages out of range due to the addition of the proposed unit at [redacted] Station 21.

5. Short Circuit Analyses

5.1. Short Circuit Model Assumptions

Transmission Planning performed short circuit analyses based on 2011 transmission system conditions. Analyses were performed with and without the existing Station 44 generators. There are several assumptions made in these short circuit analyses. These assumptions are:

1. Stations 11, 12, 64 and 66 are retired and the 115kV line between Stations 52 and 53 serving these stations is not in service.
2. Existing generation at Station 44 will be available during the commissioning stage starting in June 2011 until the start of commercial operation in December 2011, after which they will be decommissioned.
3. No significant network improvements are planned in the [redacted] Area in the foreseeable future.

System Equivalent Impedances were calculated and analyses were performed to identify any overstressed breakers on the transmission system caused by the addition of the proposed generation.

5.2. June 2011 Short Circuit Analysis Results

5.2.1. System Impedance at point of Interconnection June 2011 Conditions

The short circuit system equivalent impedance from the SCE&G transmission system that will be seen at the [redacted] Station 21 115kV bus in June 2011 is:

*Table 5.2.1.1. **June 2011** System Equivalent Impedances for [redacted] Station 21 Short Circuit Study*

Z positive (p.u.)	X/R	Z negative (p.u.)	X/R	Z zero (p.u.)	X/R
0.00847+j0.04406	5.20	0.00848+j0.04406	5.19	0.01782+j0.06466	3.63

These values are calculated on a 100 MVA base. These values do **not** include the contribution of the proposed [redacted] Station 21 generator.

5.2.2. Overstressed Breaker Analysis June 2011 Conditions

An analysis of the effect of the increased fault current in the SCE&G area for June 2011 conditions indicates that no breakers on the SCE&G transmission system will become overstressed due to the addition of the proposed [redacted] Station 21 generator.

5.3. December 2011 Short Circuit Analysis Results

The short circuit system equivalent impedance from the SCE&G transmission system that will be seen at the [redacted] Station 21 115kV bus in December 2011 is:

5.3.1. System Impedance at point of Interconnection December 2011 Conditions

Table 5.3.1.1. ***December 2011*** *System Equivalent Impedances for* [redacted] *Station 21 Short Circuit Study*

Z positive (p.u.)	X/R	Z negative (p.u.)	X/R	Z zero (p.u.)	X/R
0.00877+j0.04651	5.31	0.00879+j0.04651	5.29	0.01773+j0.06704	3.78

These values are calculated on a 100 MVA base. These values do **not** include the contribution of the proposed [redacted] Station 21 generator.

5.3.2. Overstressed Breaker Analysis December 2011 Conditions

An analysis of the effect of the increased fault current in the SCE&G area for December 2011 conditions indicates that no breakers on the SCE&G transmission system will become overstressed due to the addition of the proposed [redacted] Station 21 generator.

6. Stability Analysis

6.1. Overview of Stability Analysis

The stability study examined the effects of connecting a generator unit at [redacted] Station 21. Because of the physical proximity of the Station 23 site, the Station 21 and Station 23 sites are both effectively electrically equivalent for the purposes of a this transient stability analysis. The Station 21 site is simulated and the results are valid for both sites. The effects of the proposed generator on the SCE&G system as well as the effects of system events on the proposed generator were studied. The generator is proposed to be placed into service in the year 2011.

The stability study of the interconnection of the proposed [redacted] generator to the SCE&G transmission system assessed the ability of this generator to remain in synchronism following selected transmission system events. Also reviewed was the adequacy of the damping of generation/transmission oscillations and the impact of the proposed generator on the stability performance of other SCE&G system generators. In addition, generator frequency responses and generator protective system performance were evaluated.

Rotor angle responses of the proposed [redacted] generator were simulated in order to determine if angular instability could result from likely events. Generator frequency deviations were examined in order to determine if generator frequency responses could result in generator tripping. And the results of the loss of generation at [redacted] Station 21 were examined in order to determine if any resulting underfrequency relay operations would lead to system load shedding. Also, the effects of each event were examined in order to determine if [redacted] and SCE&G system voltages were adversely affected, particularly with respect to the V.C. Summer Nuclear Station offsite power supplies. SCE&G system responses were examined in order to identify any resulting voltage instability, transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs). Event output data and response plots are not included in this report but are available for review upon request.

An initial 30 second steady state simulation for the selected interconnection configuration was performed in order to establish that steady state conditions existed prior to fault conditions. The simulation of each event repeated the steady state condition for 1 second prior to introducing fault conditions so that the responses could be compared to the initial steady state condition. In order to determine the effects on all system generators, each event was simulated under system peak load conditions. Events were selected from the three categories specified by NERC Reliability Standards TPL-001 through TPL-003. No reasonable Category D events (TPL-004) were found for this study. The results of the stability analysis are described in the following sections and are summarized following the detailed results.

6.2. Results of Stability Analysis.

A. Steady state conditions (NERC Category A condition)

The interconnection of the proposed [redacted] generator was shown to result in system steady state conditions. Generator rotor angles and frequencies showed no significant deviations throughout the 30 second steady state (no disturbance) simulation. System voltages showed no significant deviations throughout the simulation period. There was no indication of generator or system voltage instability. No system stability limits were encountered. Nor were any transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs) found. No compliance issues for NERC Reliability Standard TPL-001-0 were found.

B. Normal clearing of a three phase fault on the [redacted] Station 21 – [redacted] Station 15 115kV Line. (NERC Category B-2 Contingency)

Following a one second steady state period, a permanent fault was simulated on the [redacted] Station 21 – [redacted] Station 15 115kV line near the Station 21 bus. With normal clearing, this results in the opening of the [redacted] Station 21 – [redacted] Station 15 115kV line 5 cycles after the appearance of the fault. The proposed unit remains connected.

Rotor angle oscillations were moderate and sufficiently damped with no indication of angular instability. Likewise, system frequency responses were also moderate and well damped with no indication of system underfrequency load shedding or generator frequency protection operations. Local system voltages were initially depressed by the presence of the fault. However, all voltages recovered once the fault was cleared and there was no indication of generator or system voltage instability. No system stability limits were encountered. Nor were any transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs) found. No compliance issues for NERC Reliability Standard TPL-002-0 were found for this event.

Steady state conditions were reestablished after the fault with no further system operations.

C. Normal clearing of a three phase fault on the [redacted] Station 52 – [redacted] Station 21 115kV Line. (NERC Category B-2 Contingency)

Following a one second steady state period, a permanent fault was simulated on the [redacted] Station 52 – [redacted] Station 21 115kV line near the Station 21 bus. With normal clearing, this results in the opening of the [redacted] Station 21 – [redacted] Station 15 115kV line 5 cycles after the appearance of the fault. The proposed unit remains connected.

Rotor angle oscillations were moderate and sufficiently damped with no indication of angular instability. Likewise, system frequency responses were also moderate and well damped with no indication of system underfrequency load shedding or generator frequency protection operations. Local system voltages were initially depressed by the presence of the fault.

However, all voltages recovered once the fault was cleared and there was no indication of generator or system voltage instability. No system stability limits were encountered. Nor were any transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs) found. No compliance issues for NERC Reliability Standard TPL-002-0 were found for this event.

Steady state conditions were reestablished after the fault with no further system operations.

D. Delayed clearing of a single phase-to-ground fault at the [redacted] Station 21 13.8kV Bus. (NERC Category C-9)

Following a one second steady state period, a single phase-to-ground fault was simulated at the [redacted] Station 21 13.8kV bus. This fault is cleared after 25 cycles by opening the 115kV lines connected to this bus, as well as disconnecting the proposed [redacted] generator and the 115/13.8kV transformer at [redacted] Station 21.

Rotor angle oscillations of all system generators were moderate and sufficiently damped with no indication of angular instability. Likewise, system frequency responses were not severe and were well damped with no indication of system underfrequency load shedding or generator frequency protection operations. Local system voltages were initially depressed by the presence of the fault. However, all voltages recovered once the fault was cleared and there was no indication of generator or system voltage instability. No system stability limits were encountered. Nor were any transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs) found. No compliance issues for NERC Reliability Standard TPL-003-0 were found for this event.

Steady state conditions were reestablished with no further system operations.

6.3. Stability Study Results Summary

A. Steady state conditions

1. Generator rotor angles demonstrate steady state condition.
2. Generator frequencies show no significant deviation.
3. There was no negative impact on V.C. Summer offsite power.
4. There were no resulting voltage instability, transient stability limits, SOL's, or IROL's.
5. No NERC Reliability Standard TPL-001-0 compliance issues were found.

B. Normal clearing of a three phase fault on the [redacted] Station 21 – [redacted] Station 15 115kV Line. (NERC Category B-2 Contingency)

1. There was no indication of transient instability.
2. There was no indication of voltage instability.
3. There was no negative impact on V.C. Summer offsite power.
4. There was no indication of system UFLS or generator frequency protection operations.
5. There were no resulting voltage instability, transient stability limits, SOL's, or IROL's.
6. No NERC Reliability Standard TPL-002-0 compliance issues were found.

C. Normal clearing of a three phase fault on the [redacted] Station 52 – [redacted] Station 21 115kV Line. (NERC Category B-2 Contingency)

1. There was no indication of transient instability.
2. There was no indication of voltage instability.
3. There was no negative impact on V.C. Summer offsite power.
4. There was no indication of system UFLS or generator frequency protection operations.
5. There were no resulting voltage instability, transient stability limits, SOL's, or IROL's.
6. No NERC Reliability Standard TPL-002-0 compliance issues were found.

D. Delayed clearing of a single phase-to-ground fault at the [redacted] Station 21 13.8kV Bus. (NERC Category C-9 Contingency)

1. There was no indication of transient instability.
2. There was no indication of voltage instability.
3. There was no negative impact on V.C. Summer offsite power.
4. There was no indication of system UFLS or generator frequency protection operations.
5. There were no resulting voltage instability, transient stability limits, SOL's, or IROL's.
6. No NERC Reliability Standard TPL-003-0 compliance issues were found.

7. Required Interconnection Facilities and Estimated Cost

No adverse System Impacts were identified in this study as part of the steady state, short circuit or stability analyses. However, due to the requested interconnection at the 13.8kV side of a 115-13.8kV delta-wye transformer and therefore, the absence of a ground source on the 115kV system at Station 21 and Station 23, conditions can exist where during a line to ground fault on the 115kV system in and around Station 21 and Station 23, the phase to ground voltages rise to phase to phase levels.

One specific example of this can exist while breaker 1513 is open for maintenance (or any other reason) and a line to ground fault occurs on the 115kV transmission line between Station 23 and Station 52. Immediately following the fault breaker 5213 at Station 52 will open. However, breakers 2312 and 2314 at Station 23 will fail to open due to an absence of fault current from the local end. This will create an isolated 115kV transmission system between breakers 1513 and 5213 with no ground source. The remaining generator at Station 21 will continue to energize this system and cause voltages to rise to phase to phase levels across phase to ground connected equipment such as lightning arrestors.

[redacted]

This situation can also occur while breaker 5213 is open for maintenance and a line to ground fault occurs on the other side of Station 23. Additionally, open breakers at Station 21 or Station 23 can setup this same situation.

For any of these scenarios, Stations 52 and 53 won't experience the rise in phase to ground voltage due to the fact that both of those Stations have multiple ground sources entering and leaving the Stations. Also, Stations 14, 15-1 and 15-2 all have wye connected transformers on the 115kV side and are therefore protected from this scenario.

To mitigate these conditions requires the upgrade of equipment on the 115kV system and the implementation of an appropriate system protection scheme. For interconnection at Station 21, improvements will be required at both Station 21 and Station 23.

<u>At Station 21:</u>

Replace all (6) Lightning Arresters on the 115kV bus	\$23,800
Install (3) pt's on the 115kV bus and (1) relay	\$120,900

<u>At Station 23:</u>

Replace (14) Lightning Arresters on the 115kV bus	\$55,000
(all arresters except high side transformer arresters)	

Total Estimated Cost of Improvements for	
Generator Interconnection at Station 21	**\$199,700**

Appendix

Generator Datasheet