Generator Interconnection System Impact Study
For

[redacted]

Queue #130

Prepared for:

[redacted]

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Prepared by:
SCE&G Transmission Planning

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Generator Interconnection System Impact Study For [redacted] near Orangeburg, SC

General Discussion

Generator Interconnection System Impact Studies (GISIS) follow Generator Interconnection Feasibility Studies, and are studies of the SCE&G transmission system considering the full output of the proposed new generation. [redacted], [redacted] requested interconnection service to be studied for Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS). System Impact Studies for Network Resource Interconnection Service (NRIS) are performed under NERC Reliability Standard TPL-001-4 and include a full power flow (thermal and voltage) test of the NERC TPL Reliability Standard Table 1 and the SCE&G Internal Transmission Planning Criteria. System Impact Studies for Energy Resource Interconnection Service (ERIS) include a reliability and operational analysis of the interconnection and interconnection facilities, but do not analyze transmission system events. ERIS for a generator submitted under the Large Generator Interconnection Procedures allows the Interconnection Customer to connect the Large Generating Facility to the Transmission System and be eligible to deliver the Large Generating Facility's output using the existing firm or non-firm capacity of the Transmission System on an "as available" basis. Therefore, if [redacted] chooses ERIS, this is a non-firm Interconnection Service and does not in and of itself convey any right to deliver electricity to any specific customer or Point of Delivery.

The [redacted] project's 113.4 MW generation facility was studied with consideration for projects in SCE&G's generator interconnection request queue; therefore, generation requests submitted before this one and the associated transmission upgrades have been included in this study. If any of the higher priority requests do not materialize, an additional study or assessment of this interconnection request may be required.

This Generator Interconnection System Impact Study is requested by [redacted] [redacted] [redacted]. In this study, [redacted] [redacted] [redacted] requested a Solar Photovoltaic (PV) plant in Orangeburg County to be interconnected to the existing SCE&G 230 kV Transmission System. This solar facility has a total generation capacity of 113.4 MW, consisting of 27 GE 1500V 4.2 MW Inverters. [redacted] requested an in-service date of 6/1/2019. This study includes power flow, short circuit/fault duty, grounding, reactive power, and stability analyses.

In this report, SCE&G Transmission Planning provides NRIS and ERIS information for the [redacted] PV plant near the Cope – Orangeburg East 230kV transmission line just south of Orangeburg City in Orangeburg County.

I. Generator Interconnection Specifications

The solar generation facility design consists of the following information:
MW: 113.4
PF: 95% lead/lag
GSU: 230/34.5 kV (WyeG-Delta-WyeG)
Speed: N/A

II. Transmission Studies

A. Power Flow Analysis

For the proposed generator interconnection at the [redacted] in Orangeburg County, Transmission Planning used the following Base Cases for the studies:

2019 Light Load Case - SERC LTSG
2019 Peak Load Case - SERC LTSG
2019 Shoulder Load Case - SERC LTSG
2020 Peak Load Case - SERC LTSG
2021 Light Load Case - SERC LTSG
2021 Shoulder Load Case - SERC LTSG
2021 Peak Load Case - SERC LTSG
2026 Peak Load Case - SERC LTSG
2026 Shoulder Load Case - SERC LTSG

Base Cases are defined as SCE&G's most up-to-date internal planning models that include currently planned transmission improvements and, also, include Generator NRIS requests with a higher priority than this request that have signed an Interconnection Agreement (including any transmission improvements associated with the higher priority NRIS requests).

Transmission constraints are limiting element/contingency(s) pairs in which the loading on the limiting element is greater than 90%. The 90% loading value accounts for actual system conditions that occur in real-time which can vary from the assumptions made in the models and simulations, and is used to include transmission constraints where small changes in expected system conditions may result in highly loaded facilities actually being overloaded. In this report, only transmission constraints resulting from the additional generation capacity of the requested generator interconnection are shown.

An initial full test of the NERC Reliability Standard Table 1 and the SCE&G Internal Transmission Planning Criteria was conducted on all Base Cases listed above. This ensured no overloaded lines or voltage violations on the SCE&G transmission system in each of these Base Cases for contingencies on the SCE&G transmission system and ensured a "no violation" starting point for these studies.

Interconnection Cases were created by modifying the Base Cases, discussed above, to include all higher priority Generator Interconnection requests in the SCE&G queue not already included in the Base Cases (including any transmission improvements associated with the higher priority requests) and to include this requested interconnection.

NRIS Results

For this request, a single solar photovoltaic plant totaling 113.4 MW's connected to the Cope – Orangeburg East 230 kV line was modeled in each of the Interconnection Cases. As examples, the tables below show results of the N-1-1 evaluation for the most severe loadings with [redacted] off and on. The tables show the following: the Limiting Element and its rating, 1) the Interconnection Case studied, 2) the first contingency analyzed, 3) the second contingency analyzed, 4) the power flow on the limiting element without [redacted] interconnected during the specified contingencies, 5) the resulting % loading on the limiting element without [redacted] interconnected during the specified contingencies, 6) the power flow on the limiting element with [redacted] interconnected and producing 113.4 MW during the specified contingencies, and 7) the resulting % loading on the limiting element with [redacted] producing 113.4 MW during the specified contingencies.

For NRIS, the results (as shown in Tables 1 and 2 below) indicated that beginning in 2021 the Orangeburg East transformers would load above 90% given certain contingencies. SCE&G recognizes that even without [redacted] online there are contingencies that cause loading on these transformers just above 90%. However, with [redacted] online, the contingency loading on the Orangeburg East transformers increase 4 to 5 %. Currently, SCE&G uses Operating Guides to alleviate this contingency loading when necessary. This can include reconfiguring the transmission system or re-dispatching generation. Studies show using Operating Guides are sufficient to alleviate loading throughout a 10 year planning window, therefore no upgrades are required for the limiting elements shown in Tables 1 and 2 below. However, re-dispatch costs may be allocated to the Transmission Service Request that identifies the [redacted] project as a resource, as appropriate, during these conditions.

Tables 3 and 4 below show that there are two transmission lines on the SCE&G system that, when outaged, cause two SCE&G facilities to overload. [redacted] will overload to 181% and the [redacted] will overload to 112%. An outage of the [redacted] and the [redacted] 230kV line causes these overloads. To prevent these overloads [redacted] will need to build an additional line into its facility. SCE&G proposes building a new 230kV line from the [redacted] to [redacted]. This new 6.8 mile 230kV transmission line will need to be bundled 795 ACSR at a cost of $8,160,000 and would take 24 months to complete. This additional source will

address the constraints listed in Tables 3 and 4 below. See Figure 1 for the single line drawing required for NRIS, and costs are described in Section IV.A of this report.

Table 1						
Limiting Element: Orangeburg East 230/115 Transformer #1 (336MVA)						
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Case	**Contingency 1**	**Contingency 2**	**Contingency Flow without [redacted] (MVA)**	**% Loading without [redacted]**	**Contingency Flow with [redacted] (MVA)**	**% Loading with [redacted]**
2021 S	[redacted]	[redacted]	307.00	91.37	318.14	94.68
2021 S	[redacted]	[redacted]	298.28	88.77	307.28	91.45
2026 S	[redacted]	[redacted]	308.26	91.74	325.60	96.90
2026 S	[redacted]	[redacted]	298.49	88.84	307.52	91.52

Table 2						
Limiting Element: Orangeburg East 230/115 Transformer #2 (336MVA)						
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Case	**Contingency 1**	**Contingency 2**	**Contingency Flow without [redacted] (MVA)**	**% Loading without [redacted]**	**Contingency Flow with [redacted] (MVA)**	**% Loading with [redacted]**
2021 S	[redacted]	[redacted]	306.92	91.34	324.18	96.48
2021 S	[redacted]	[redacted]	296.38	88.21	305.37	90.88
2026 S	[redacted]	[redacted]	306.18	91.12	323.45	96.27
2026 S	[redacted]	[redacted]	296.58	88.27	305.61	90.95

Table 3						
Limiting Element: [redacted])						
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Case	**Contingency 1**	**Contingency 2**	**Contingency Flow without [redacted] (MVA)**	**% Loading without [redacted]**	**Contingency Flow with [redacted] (MVA)**	**% Loading with [redacted]**
All Cases	[redacted]	[redacted]	139.78	100.85	251.70	181.65

Table 4						
Limiting Element: [redacted]						
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Case	**Contingency 1**	**Contingency 2**	**Contingency Flow without [redacted] (MVA)**	**% Loading without [redacted]**	**Contingency Flow with [redacted] (MVA)**	**% Loading with [redacted]**
All Cases	[redacted]	[redacted]	139.78	62.40	251.70	112.39

ERIS Results
An outage of the [redacted] or the [redacted] 230kV line may require [redacted] to disconnect. This is to ensure no overload on the [redacted] and the [redacted] should the next contingency happen. Tables 3 and 4 as shown above show the results in more detail. See Figure 2 for the single line drawing required for ERIS and costs are described in Section IV.B of this report.

For NRIS and ERIS, with respect to voltage, the results of the test conducted in accordance with the NERC TPL Reliability Standard Table 1 and the SCE&G Internal Transmission Planning Criteria did not result in any voltage violations due to this generator interconnection.

B. Short Circuit Analysis

A short circuit analysis was performed to assess the impact of the addition of the proposed Solar PV plant to the SCE&G Transmission System. The analysis shows no overstressed breakers on the SCE&G Transmission System due to the proposed Solar PV plant.

C. Stability Analysis

1. <u>Overview of Stability Analysis</u>

The stability study examined the effects of connecting the [redacted] plant consisting of 27 GE 1500V 4.2 MW Inverters connected to SCE&G's 230 kV system through a 230/34.5 kV step-up transformation on the Cope – Orangeburg East 230 kV line in Orangeburg County. The effects of the proposed generator on the SCE&G system as well as the effects of system events on the proposed generators were studied. The base cases used in the stability study were the following:

- 2019 Peak Load Case - MMWG
- 2019 Light Load Case - MMWG

These are the current and most up-to-date base cases for the time periods selected for study.

The stability study of the interconnection of the Solar PV plant to the SCE&G Transmission System assessed the ability of this generator to remain in synchronism following selected transmission system contingencies. 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 system generators. In addition, generator frequency responses and generator protective system performance were evaluated.

Phase locked loop (PLL) angle responses of the Solar PV plant were simulated in order to determine if angular instability could result from likely contingencies. Generator frequency deviations were examined in order to determine if generator frequency protection could result in generator tripping. The results of the loss of generation at the Solar PV plant were examined in order to determine if any resulting underfrequency relay operations would lead to system load shedding. Also, the effects of each contingency were examined in order to determine if SCE&G voltages were adversely affected. 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). Contingency output data and response plots are not included in this report but are available for review upon request.

An initial 20 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 contingency repeated the steady state condition for one second prior to introducing permanent 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 contingency was simulated under system peak load conditions. Contingencies were selected in order to satisfy several of the categories as specified by NERC Reliability Standard TPL-001-4. No valid Extreme Event contingencies were applicable to this study. The results of the stability analysis are described in the following sections and are summarized following the detailed results.

2. Results of Stability Analysis

A. Steady State Conditions. (NERC Category P0 condition)

The interconnection of the [redacted] PV plant was shown to result in system steady state conditions. Generator rotor angles and frequencies showed no deviations throughout the 20 second simulation. System voltages showed no deviations throughout the simulation period. There was no indication of generator or system voltage instability. No system stability limits were encountered. There were no transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs) found.

B. Normal clearing of a three phase fault on the 230 kV tap from which the Solar PV plant is to be served. (NERC Category P1 Contingency)

Following a one second steady state period, a permanent fault was simulated on the [redacted] 230 kV tap. This resulted in opening two of the three ring bus breakers six cycles after the appearance of the fault, then reclosing 26 cycles later and finally opening six cycles after that. Since the [redacted] 230 kV tap is the only connection point between the proposed Solar PV plant and the SCE&G 230 kV network, the proposed unit would no longer be connected and would therefore trip.

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. No generator frequency protection operations were indicated.

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. There were no transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs) found.

Steady state conditions were reestablished with no further system operations.

C. Normal clearing of a three phase fault at the [redacted]. (NERC Category P2 Contingency)

Following a one second steady state period, a permanent fault was simulated at the [redacted] The fault is cleared after six cycles, resulting in the opening of 4 230 kV lines at the [redacted].

Rotor angle and Phase Locked Loop angle oscillations were moderate and well 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 operations. No generator frequency protection operations were indicated.

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. There were no transient stability limits, system operating limits (SOLs), or interconnection reliability operating limits (IROLs) found.

Steady state conditions were reestablished with no further system operations.

D. Delayed clearing of a three phase fault at the [redacted] (NERC Category P5)

Following a one second steady state period, a three phase fault was simulated at the [redacted] This fault was cleared after 60 cycles by first opening the 230 kV lines at [redacted] at 27 cycles and then opening the 230/115 kV transformer at [redacted] at 60 cycles.

Rotor angle and Phase Locked Loop 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 operations. No generator frequency protection operations were indicated.

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.

Steady state conditions were reestablished with no further system operations.

STABILITY STUDY RESULTS SUMMARY

A. Steady state conditions

1. Generator rotor angles demonstrate steady state condition.
2. Generator frequencies show no deviation.
3. There are no voltage instabilities, transient instabilities, SOLs, or IROLs.

B. Normal clearing of a three phase fault on the 230 kV tap from which the Solar PV plant is to be connected. (NERC Category P1 Contingency)

1. There was no indication of system UFLS or generator overfrequency operation.
2. There were no resulting voltage instabilities, transient instabilities, SOLs, or IROLs.

C. Normal clearing of a three phase fault at the [redacted]. (NERC Category P2 Contingency)

1. There was no indication of system UFLS or generator overfrequency operation; however, facility frequency protection should be coordinated with system frequency protection plan.
2. There were no resulting voltage instabilities, transient instabilities, SOLs, or IROLs.

D. Delayed clearing of a three phase fault at the [redacted]. (NERC Category P5)

1. There was no indication of system UFLS or generator overfrequency operation; however, facility frequency protection should be coordinated with system frequency protection plan.
2. There were no resulting voltage instabilities, transient instabilities, SOLs, or IROLs.

III. General Engineering Design

A. Engineer Single line Layout for NRIS

[redacted]

Figure 1

B. Engineer Single line Layout for ERIS

[redacted]

Figure 2

C. Site Map for [redacted]

[redacted]

Figure 3

IV. Transmission and Substation Cost Estimate

A. Network Resource Interconnection Service (NRIS)

SCE&G studies NRIS at peak load and non-peak load conditions under a variety of severely stressed conditions to determine whether, with the Large Generating Facility at full output, the aggregate of generation in the local area can be delivered to the aggregate of load on SCE&G's transmission system while meeting the requirements of the NERC TPL Standard and SCE&G's Internal Planning Criteria. NRIS is a firm service and this approach ensures compliance with planning standards and criteria while providing this firm service.

Scope of Work	Estimated Cost[1]	Time to Complete[2]
Make modifications to the SCE&G Transmission System to provide a Generator Interconnection on the Cope – Orangeburg East 230kV line adjacent to the [redacted] project. **(See Figure 1)**		
- Construct an SCE&G-owned 230 kV switching station using a four terminal straight-bus design: Install four 230 kV Circuit Breakers, structures, foundations, switches, PT's, CT's, batteries, revenue quality metering, SCADA, station service, lightning arresters, gravel, fencing and ground grid. Replace relay panels at Cope and Orangeburg East to accommodate fold-in.	$4,379,600	15 months
- Construct a fold-in of the Cope – Orangeburg East 230kV line. This assumes folding the B-795 ACSR line into a four breaker switching station. Install two self-supporting steel dead ends in line and each leg of the fold-in will have a steel tangent pole. This assumes the switching station is no longer than 600 ft. from the existing transmission R/W. Public Service Commission approval/permit may be required.	$ 344,000	15 months
- Construct a new 230kV line from the [redacted] to the [redacted] Substation. This assumes the line will be constructed with B-795 ACSR into a 4 breaker switching station. Additional Right of Way and Public Service Commission approval/permit will be required.	$ 8,160,000	24 months
TOTAL Required for NRIS	**$12,883,600**	**24 months**
1. Estimated Costs based on future required In-service date. Costs do not include site cost, site preparation, road access or Right of Way procurement if needed. 2. Design, procurement and construction time is estimated to be 24 months. Within that period, the site would need to be prepared and ready 12 months prior to the required completion date. Equipment procurement assumes normal lead times for structures and major equipment and timing for construction to allow an off-peak outage of the transmission equipment involved. Time to Complete does not include time to acquire site, Right of Way if needed, or possible delays in regulatory approval.		

B. Energy Resource Interconnection Service (ERIS)

SCE&G studies ERIS at peak load and non-peak load conditions under base case conditions and does not include an analysis of system events.

Scope of Work	Estimated Cost[1]	Time to Complete[2]
Make modifications to the SCE&G Transmission System to provide a Generator Interconnection on the Cope – Orangeburg East 230kV line adjacent to the [redacted] project. **(See Figure 2)**		
- Construct an SCE&G-owned 230 kV switching station using a three terminal ring-bus design: Install three 230 kV Circuit Breakers, structures, foundations, switches, PT's, CT's, batteries, revenue quality metering, SCADA, station service, lightning arresters, gravel, fencing and ground grid. Replace relay panels at [redacted] and [redacted] to accommodate fold-in.	$4,000,000	15 months
- Construct a fold-in of the Cope – Orangeburg East 230kV line. This assumes folding the B-795 ACSR line into a 3 breaker switching station. Install two self-supporting steel dead ends in line and each leg of the fold-in will have a steel tangent pole. This assumes the switching station is no longer than 600 ft. from the existing transmission R/W. Public Service Commission approval/permit may be required.	$ 344,000	15 months
TOTAL Required for ERIS	**$4,344,000**	**15 months**
1. Estimated Costs based on future required In-service date. Costs do not include site cost, site preparation, road access or Right of Way procurement if needed. 2. Design, procurement and construction time is estimated to be 15 months. Within that period, the site would need to be prepared and ready 12 months prior to the required completion date. Equipment procurement assumes normal lead times for structures and major equipment and timing for construction to allow an off-peak outage of the transmission equipment involved. Time to Complete does not include time to acquire site, Right of Way if needed, or possible delays in regulatory approval, if needed.		

V. Summary

This Generator Interconnection System Impact Study assessed the impact of interconnecting the [redacted] generation facility consisting of a total NET summer/winter rating of 113.4 MW. The cost associated with NRIS for [redacted] is $12,833,600. The cost associated with ERIS is $4,344,000.

This report provides an estimated cost and time required to make the modifications needed to provide the requested generator interconnection. Based on these estimates, the proposed in service date of 6/1/2019 is achievable. The Time to Complete will commence at the conclusion of the study process and after all appropriate agreements have been signed and deposits received. Since this is a 230kV interconnection, if regulatory approval is required, this may impact the Time to Complete.