Generator Interconnection System Impact Study For

[redacted]

Prepared for:

[redacted]

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SCE&G Transmission Planning

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General Discussion

Generator Interconnection System Impact Studies (GISIS) follow Generator Interconnection Feasibility Studies, and are detailed studies of the SCE&G Transmission System considering the full output of the proposed new generation. System Impact Studies for Network Resource Interconnection Service (NRIS) include a full test of the NERC TPL Reliability Standards Table 1 and the SCE&G Internal Transmission Planning Criteria.

The [redacted] [redacted] [redacted] 74.9 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] SCE&G is an affected system and was requested to study the impact of the proposed generation on the SCE&G transmission system. In this study, [redacted] requested a Solar Photovoltaic (PV) plant in [redacted] to be interconnected to the existing Duke Energy Progress 230 kV Transmission System. This solar facility has a total generation capacity of 74.9 MW, consisting of 19 GE LV5 series 4 MW Inverters. [redacted] requested an in-service date of 6/1/2016. [redacted] [redacted] [redacted] [redacted] requested study of Network Resource Interconnection Service (NRIS) to assess the amount of capacity which can be interconnected to Duke Energy Progress 230kV system as a qualifying facility. This study includes power flow (thermal and voltage), short circuit/fault duty, grounding, reactive power and stability analyses.

In this report, SCE&G Transmission Planning provides NRIS information for the [redacted] PV plant near the [redacted] line in [redacted]

I. Generator Interconnection Specifications

The solar generation facility design consists of the following information:

MW: 74.9
PF: 90% lead/lag
GSU: 230/34.5 kV (Delta-WyeG)
Speed: N/A

II. Transmission Studies

A. Power Flow Analysis

This study is based on current transmission expansion plans. Any changes to the schedule of transmission projects, generation additions or generation retirements could affect the results of this study.

[redacted] has requested to connect to the existing [redacted], however, SCE&G has plans to build a new substation called [redacted] with an in-service date of May 2016 that will fold-in the [redacted] This will cause the [redacted] ultimately to be connected to the [redacted]. The results and cost estimates included in this report assume the [redacted] is in service by May 2016. To interconnect the [redacted] to the existing grid and accommodate NRIS, a transfer trip scheme must be installed from the [redacted] to the proposed customer 230 kV switching station. The estimated cost for SCE&G for this transfer trip scheme is $40,000 (see Figure 1).

For the proposed generator interconnection on the [redacted], Transmission Planning used the following base cases for the studies:

2016 Light Load Cases - SERC LTSG
2016 Peak Load Cases - SERC LTSG
2017 Shoulder Load Cases - SERC LTSG
2018 Peak Load Cases - SERC LTSG
2021 Light Load Cases - SERC LTSG
2021 Shoulder Load Cases - SERC LTSG
2021 Peak Load Cases - SERC LTSG
2026 Peak Load Cases - SERC LTSG

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

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.

This report identifies transmission constraints that occurred in the generator interconnection cases that did not occur in the base cases (*i.e.*, in the base cases prior to the addition of [redacted] generator facility). There are no overloaded transmission facilities on the SCE&G transmission system in the base cases.

The full test of the NERC TPL Reliability Standards Table 1 and the SCE&G Internal Transmission Planning Criteria were tested against two sets of cases for each of the models listed above: one not including this generator interconnection (the base case) and one including this generator interconnection (the interconnection case) and then a comparison analysis was conducted to identify transmission constraints due to the requested interconnection. These tests resulted in no overloaded lines on the SCE&G transmission system for contingencies on the SCE&G transmission system.

With respect to voltage, the results of the test conducted in accordance with the NERC TPL Reliability Standards 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], [redacted] PV plant consisting of 19 4000kW solar inverters connected to Duke Energy Progress 230 kV system through a 230/34.5 kV step-up transformation on the [redacted] 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:

- 2013 MMWG 2015 Summer Case
  - SCE&G area updated with 2016 Summer model including Dynamic Load Model (DLM) data
- 2013 MMWG 2014 Light Load Case
  - SCE&G area updated with 2016 Light Load model including Dynamic Load Model (DLM) data

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 each of three categories as specified by NERC Reliability Standards TPL-001 through TPL-003. No valid Category D contingencies (TPL-004) 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. <u>Results of Stability Analysis</u>

A. Steady State Conditions. (NERC Category A/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 B-2/P1 Contingency)

Following a half second steady state period, a permanent fault was simulated on the [redacted] This resulted in the opening the breakers on both ends of the [redacted] six cycles after the appearance of the fault, then reclosing 26 cycles later and finally opening six cycles after that. Since the [redacted] is the only connection point between the proposed Solar PV plant and the SCE&G/DEP 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 C-1/P2 Contingency)

Following a half second steady state period, a permanent fault was simulated at the [redacted]. The fault is cleared after six cycles, resulting in the opening of 2 230 kV lines and 2 230/115kV transformers 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 C-9/P3 & P4)

Following a one second steady state period, a three phase fault was simulated at the [redacted]. This fault was cleared after 93 cycles by first opening the 230 kV tielines 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 B-2/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 C-1/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.

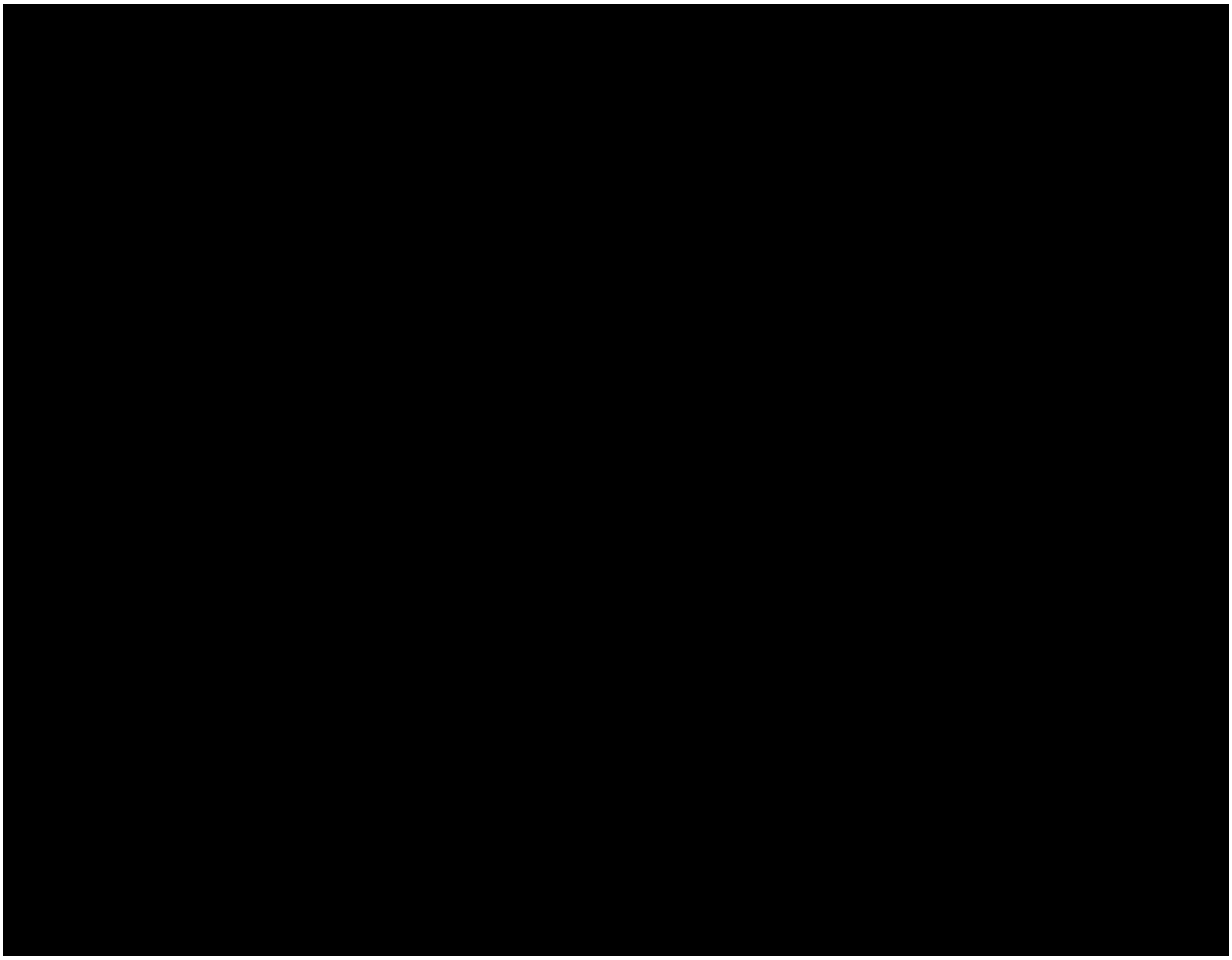
D. Delayed clearing of a three phase fault at the [redacted]. (NERC Category C-9/P3 & P4)

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

[redacted]

Figure 1



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 Standards 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 [redacted] adjacent to the [redacted]. **(See Figure 1 and 2)**		
- A transfer trip scheme must be installed from the [redacted] to the proposed customer switching station.	$40,000	6 months
TOTAL Required for Interconnection	**$40,000**	**6 months**
1. Estimated Costs based on future required In-service date. 2. The time to complete estimate assumes the [redacted] station is in service by May 2016.		

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 74.9 MVA. Although this generator interconnection will not be connected to an SCE&G facility, SCE&G is an affected system and this study indicates that transmission upgrades on the SCE&G transmission system are required. This report provides an estimated cost and time required to make the modifications needed to provide the requested generator interconnection. The 6 month 'Time to Complete' will commence at the conclusion of the study process and after all appropriate agreements have been signed.