

System Impact Study

prepared for



04/12/21

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1.0 Summary

[REDACTED] has requested a System Impact Study to evaluate the impact to the Public Service Company of Colorado (PSCo) system from the interconnection a 4.5 MW hydroelectric generation site. The site will be interconnected to the Vineland Substation on distribution feeder 1412 with a Point-of-Interconnection voltage of 13.2kV. The analysis within this report outlines the impacts of this generation on the distribution feeder system, and the substation. Metering requirements are not included in this study and shall be provided directly from the PSCo metering group.

2.0 Summary of Distribution Impacts

Distribution feeder and substation impacts were identified during the evaluation of the new hydroelectric generation site. Details on these impacts shall be provided in later sections, but an overview of those impacts is provided below.

1. The proposed generation will exceed distribution feeder Minimum Daytime Load (MDL) and High Daytime Load (HDL), resulting in backfeed to the substation medium voltage bus.
2. Under MDL conditions, proposed generation will exceed feeder and substation load, resulting in backfeed into transmission.
3. There is a potential for short-term islanding of generation and load on the distribution feeder.
4. Generation shall require a distribution line extension to new site.
5. Under certain 69kV fault conditions, generation could cause high-voltage impacts on the high-side of the substation transformer.
6. With proposed generation the capacity available to PSCo at the distribution substation transformer at Vineland is reduced, impacting PSCo's future distribution needs. This will limit the amount of Distributed Energy Resources (DER) PSCo can accommodate on its system without substation transformer upgrades.

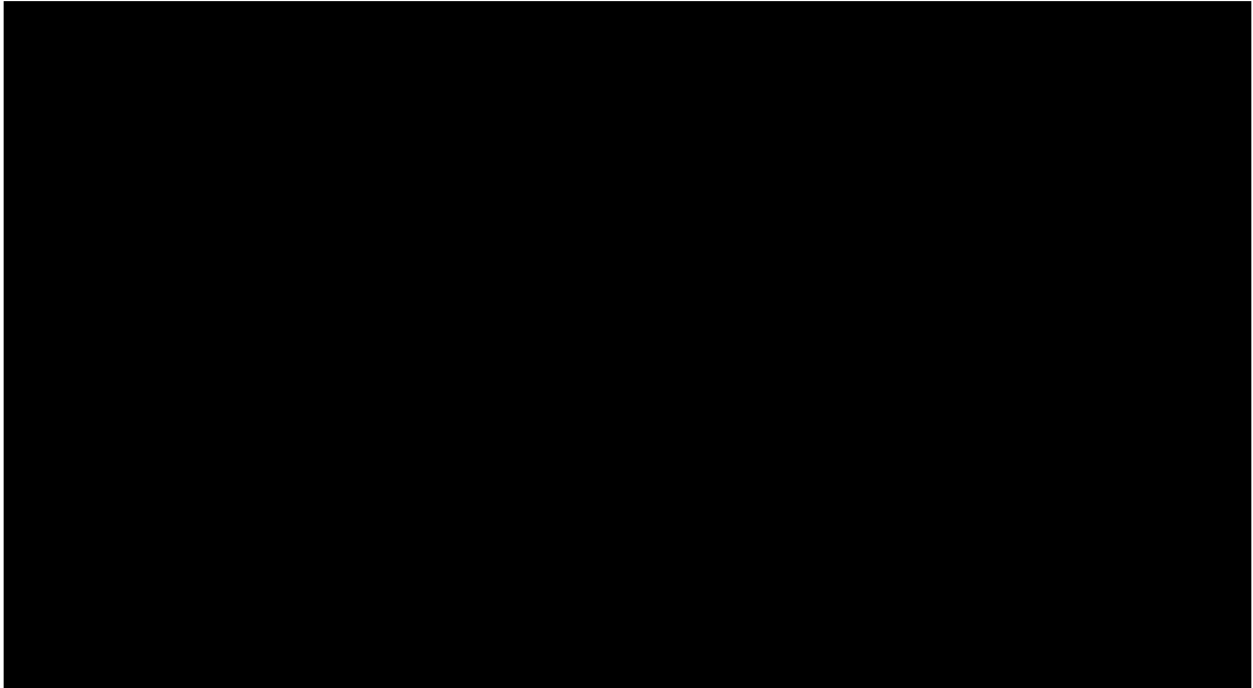
As a result of these impacts, multiple mitigations are required. These mitigations are outlined in section 4, with costs provided in section 5. A summary of mitigation is as follows:

1. Feeder protection upgrades shall be required at the Vineland substation, which include the replacement of the distribution feeder relaying and addition of Direct Transfer Trip (DTT).
2. New distribution feeder conductor will be required to interconnect to the proposed generation site.
3. Transformer capacity upgrades shall be required at Vineland Substation.
4. Telemetry from the new generation to the PSCo control center is required.
5. PSCo recloser is required at the generation POI.
6. Replacement of transformer surge arrestors shall be required.

3.0 Study Scope

The study evaluated the impact to the PSCo Vineland distribution system and substation due to the interconnection of the proposed hydroelectric generation resource. The proposed generation is located on Vineland Feeder 1412 and is located approximately [REDACTED] circuit miles from the substation. The proposed generation size is 4.5MW with a power factor capability of +/- 0.9 with a generation voltage of 4.16kV. The system impact study utilized drawings and technical data provided by the facility operator and their consultants in this analysis. Deviations to any drawings or designs reviews within this report may require additional studies. Since the incremental capacity from GI-2020-17 only results in minimal increase to the current net flow on the transmission system from the generator, a transmission study was not deemed necessary.

Figure 1 Substation Layout Overview



3.1 Study Criteria

Distribution Study Criteria:

The following criteria were utilized for the distribution system evaluation:

Thermal Loading: <=100% Normal facility rating

Stead State Voltage range: 0.95 to 1.05 per unit

Voltage Fluctuations: <=3% nominal

Existing Substation Generation Distribution System Capacity for PSCo feeders shall be maintained.

3.2 Distribution Modeling Assumptions

The study included the following distribution level assumptions. Deviations from these assumptions may require additional studies.

1. Maximum generation of 4.5MW was used to determine impacts during HDL and MDL periods.

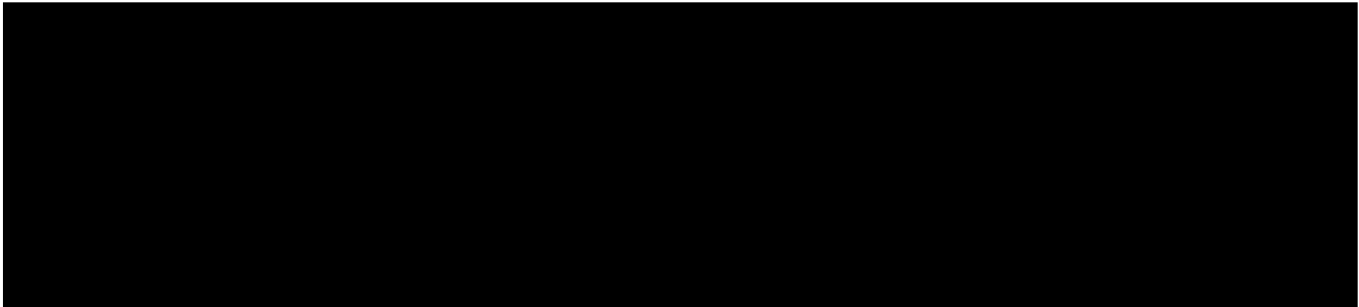
2. Power factor was studied at 0.9 and at 1.0 to study for a range of operations
3. No switching of generation within the PSCo distribution system was studied.
4. Existing hydroelectric generation site will be decommissioned prior to the commissioning of the proposed hydroelectric generation.

4.0 Study Analysis

4.1 Distribution Evaluation Results

A. Distribution Feeder and Substation Backfeed Power

Under MDL conditions with proposed generation at maximum there will be a backfeed of power at both the distribution feeder level and the substation transformer level. These values are provided in table 1.



B. Substation Generation Distribution System Capacity

The backfeed of power during MDL conditions will result in a reduction of capacity available to PSCo at the Vineland Substation. The substation transformer has a top rating of [REDACTED] which also represents the maximum generation capacity of the substation. The [REDACTED] of backfeed will reduce the available capacity to [REDACTED]. Total feeder generation capacity exceeds [REDACTED]. Therefore, the interconnection will affect the ability to fully utilize the substation, including exporting power to the transmission system from future distribution connected resources and additional transmission flow across the substation. Substation upgrades (replacement of the substation transformer) shall be required. Transformer replacement shall utilize standard transformer capacities and will be sized in order to accommodate the backfeed while maintaining the existing capacity available without the generation interconnected. Costs for these upgrades are provided.

C. Distribution System Protection Evaluation

A Point-Of-Interconnection (POI) recloser shall be installed at the customer tap location and will provide phase and ground time overcurrent protection, as well as Direct-Transfer-Trip capabilities (DTT). DTT will be required for this installation, as the machine is a synchronous generator and could potentially create an islanding condition with the feeder. The recloser may be used for operational control by the PSCo during switching or operational events that would require the generation to be offline.

The customer's proposed protection provided below is acceptable for the interconnection to proceed, provided they are limited to 4.5MW. Settings for the phase and ground overcurrent settings on the 4kV and high side of the transformer are provided below in table 2 and 3. The high-side settings being proposed are the slowest possible settings allowed based on upstream coordination.

Table 2 Required Generation Site Phase and Ground Overcurrent Setting on 4KV Side of Transformer

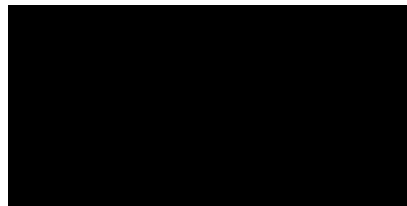
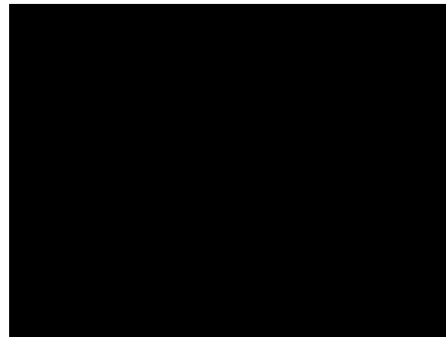
A large black rectangular redaction box covers the content of Table 2, which would otherwise contain the required generation site phase and ground overcurrent settings for the 4KV side of the transformer.

Table 3 Proposed Generation Site Phase and Ground Overcurrent Setting on High Side of Transformer



The effective grounding requirements have not been met, specially the requirement for $2.0 \cdot X1 \leq X0 \leq 2.5 \cdot X1$. Updates will need to be made to ensure the design has met the requirements. Voltage and frequency also require updating to meet interconnect guidelines. Settings will utilize 0.16 second delays for their fast-tripping voltage and frequency settings. A summary of the voltage and frequency settings along with corrections is provided in table 4. Lastly, there is a gap in the transformer protection zone of protection from the Point of Interconnection to the transformer high side CT. The customer relaying would not be able to pick up on a fault within that zone (including inside the J71) breaker and would rely on the Xcel POI recloser to clear those faults.

Table 4 Required Generation Site Phase and Ground Overcurrent Setting on 4K Side of Transformer

Customer Voltage & Frequency Set Points			Xcel Requirement	
Element	Set Point	Trip time (seconds)	Setpoint	Trip Time (seconds)
Undervoltage	88%	[REDACTED]	$50\% \leq V \leq 88\%$	2
Undervoltage	50%		$V \leq 50\%$	0.16
Oversvoltage	110%		$110\% \leq V \leq 120\%$	1
Oversvoltage	120%		$V > 120\%$	0.16
Overfrequency	60.5 Hz		$F > 60.5$	0.16
Underfrequency	58.3 Hz		$57 - 59.8 \text{ Hz}$	0.16 - 300
Underfrequency	57 Hz		$F < 57 \text{ Hz}$	0.16

D. Substation System Protection Evaluation

Due to generation backfeed at both the distribution feeder and substation transformer level, protection upgrades shall be required at the substation level. As mention in the distribution system protection evaluation, DTT is required. Updated relaying and controls shall be required on Vineland feeder 1412 to accommodate this requirement. Additionally, the substation recloser may require replacement to integrate the new control and therefore was estimated in the costs provide within this report.

The Vineland Substation transformer shall be replaced to maintain existing available capacity. It shall be installed per current PSCo standards and will include a 69kV circuit breaker, standard transformer relaying package, and high-side voltage transformers. Replacement of the transformer shall also require the addition of a control house for new transformer and 69kV breaker relaying and controls.

E. Switching

Switching of generation from the 1412 feeder to other PSCo feeders is prohibited. The generation will need to be offline during any switching condition where the generation would flow onto any feeder other than the Vineland 1412 feeder. PSCo may utilize the POI recloser for this purpose.

F. Distribution Line Extensions

Vineland feeder 1412 shall be extended to reach the new generation site POI. This distance is estimated to be at least 1,000 feet. The cost for this is provided within the report. Actual distance will be determined during facility design stage, along with distribution costs.

G. Voltage and Power Quality

Analysis did not indicate any voltage violations (steady state or fluctuation) at the medium-voltage level for the export of generation. If under actual operating conditions, steady state or voltage fluctuation values, are measured that are outside of PSCo standard limits or the generation negatively impacts PSCo equipment or customer power quality and reliability, the generation will need to be disconnected until it can return values to within limits. Limits are provided below.

Stead State Voltage Range: 0.95 to 1.05 per unit

Voltage Fluctuations: <=3% nominal

H. Telemetry

The new site will have a significant impact on the power flow at the PSCo feeder and substation level. Telemetry shall be required from the site to PSCo operations for monitoring of analog and status values.

I. Power Factor

The new site will be able to operate at a 1.0 power factor. PSCo reserves the right to adjust that power factor within a +/-0.95PF range.

5.0 Cost Estimates and Assumptions

PSCo has developed indicative cost estimates for distribution upgrades required for the interconnection of the proposed site. The cost estimates are in 2021 dollars with escalation and contingencies applied. Allowances for Funds Used During Construction (AFUDC) and gross-up for taxes are not included. These estimated costs include all applicable labor and overheads associated with the siting, engineering, design, and construction of the new PSCo facilities. This estimate does not include the cost for any Customer owned equipment and associated design and engineering and does not include the cost of any wheeling charges over the PSCo transmission or distribution system. Scoping level estimates will be provided upon completion of the facility study process.

- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- PSCo (or its Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- Line outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested back feed date due.
- Outage availability could potentially extend project timeline.



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Table 5 PSCo Distribution and Substation Facilities

Element	Description	Cost Est.
Vineland Feeder 1412	POI recloser with DTT relaying and controls	\$125,000
	Conductor Additions to Reach New POI	\$100,000
Time Frame	Site, design, procure and construct	6 Months

Element	Description	Cost Est.
Vineland Substation	Replacement of Substation Transformer and Associated Upgrades.	\$2,650,000
	Feeder 1412 Relaying and Control Upgrade (Includes DTT)	\$462,000
Time Frame	Site, design, procure and construct	24+ Months