Energy Storage System Location Study
For: Puget Sound Energy

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1. Introduction

Puget Sound Energy (PSE) engaged Power Systems Consultants (PSC) to perform a qualitative and quantitative analysis for siting a possible Energy Storage System (ESS) within the PSE electrical system. PSE filed a draft All-Source Request for Proposals (RFP) for peak capacity resources on May 4, 2020. Interconnection studies of an ESS onto a transmission system can result in the need for significant and costly network upgrades, depending upon interconnection location. This report serves as a starting point for proponents or bidders into the RFP as an aid to determine potential / lower risk locations (with respect to network upgrade costs) for interconnection of energy storage resources (and others) into PSE's transmission system.

The ESS is expected to perform in a manner consistent with the FERC defined Network Resource Interconnection Service. In general, this study is like a Feasibility Study in concept, but not necessarily in scope. Screening techniques examined the potential ESS capacity available at several Puget stations. Detailed analysis (like those completed for a Feasibility Study) was not performed.

The FERC definition of Network Resource Interconnection Service (below) can be used as a contextual guide in order to understand the purpose of this study.

Network Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission System (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market based congestion management, in the same manner as Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

Transmission Provider must conduct the necessary studies and construct the Network Upgrades needed to integrate the Large Generating Facility (1) in a manner comparable to that in which Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an ISO or RTO with market based congestion management, in the same manner as Network Resources. Network Resource Interconnection Service Allows Interconnection Customer's Large Generating Facility to be designated as a Network Resource, up to the Large Generating Facility's full output, on the same basis as existing Network Resources interconnected to Transmission Provider's Transmission System, and to be studied as a Network Resource on the assumption that such a designation will occur.

The Interconnection Study for Network Resource Interconnection Service shall assure that Interconnection Customer's Large Generating Facility meets the requirements for Network Resource Interconnection Service and as a general matter, that such Large Generating Facility's interconnection is also studied with Transmission Provider's Transmission System at peak load, 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 Transmission Provider's Transmission System, consistent with Transmission Provider's reliability criteria and procedures. This approach assumes that some portion of existing Network Resources are displaced by the output of Interconnection Customer's Large Generating Facility. Network Resource Interconnection Service in and of itself does not convey any right to deliver electricity to any specific customer or Point of Delivery. The Transmission Provider may also study the Transmission System under non-peak load conditions. However, upon request by the Interconnection Customer, the Transmission Provider must explain in writing to the Interconnection Customer why the study of non-peak load conditions is required for reliability purposes.

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1.1. Disclaimer

Note that all the information used for the study is available to any member of the public either directly (i.e., geo-location from the Department of Homeland Security) or via non-disclosure agreements with the Western Electricity Coordinating Council (for WECC base cases).

Some information (one-lines and station configurations) used (as an analytical aid) is based on FERC Form 715 submissions that pre-date (circa October 2001) the CEII classification of FERC 715 data. Station configurations and interconnections were confirmed with recent imagery.

The best possible data and analytical technique was used for this study; however, no warranty is offered by Power Systems Consultants for fitness of use of any data associated with this report or the contents of the report itself. PSC did not perform a purposeful review of base cases, maps, or one-lines for accuracy.

This study was completed outside of the OATT and is intended to broadly inform interested readers. It does not replace any OATT driven processes or documentation, nor is it intended to do so. The results in this document do not indicate that available transmission exists or that a station is suitable for interconnection from an official FERC LGIA process viewpoint.

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1.2. Energy Storage System (ESS) Discussion and Example

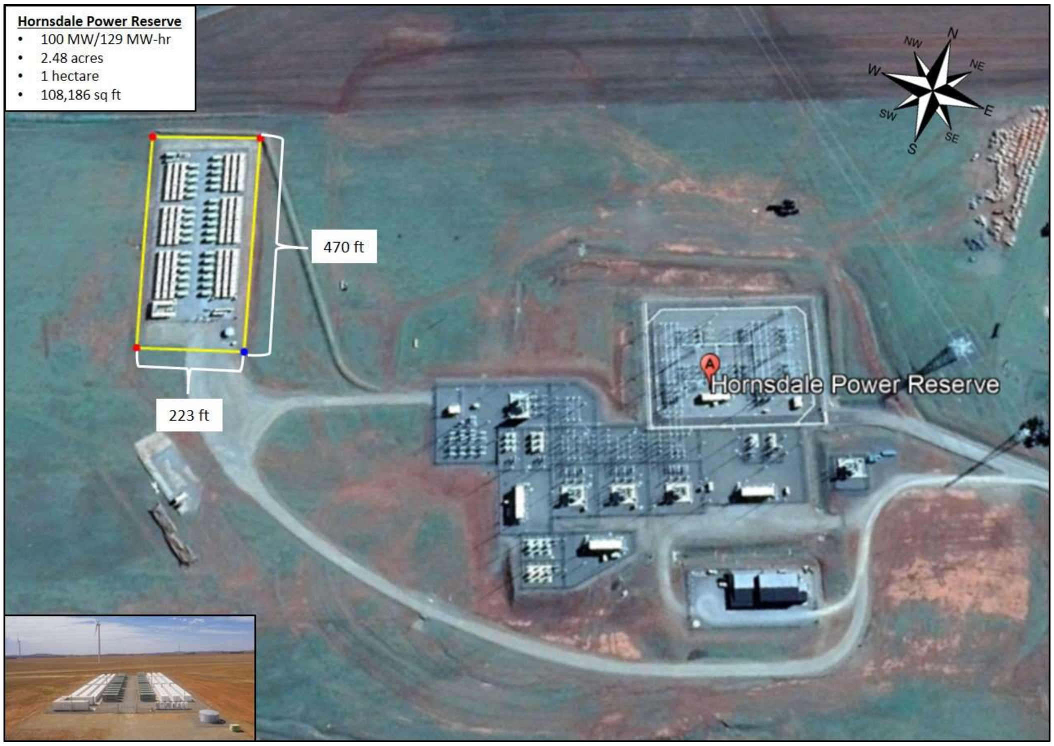
Modern utility scale ESS's store energy in the form of electro-chemical or mechanical energy, then convert that energy into electrical energy when appropriate, based on sophisticated control schemes.

Examples of electro-chemical storage include Lead Acid, Nickel-Cadmium, Lithium-Ion, and Molten Salt amongst others. Flow batteries are another type of electro-chemical battery, with Redox being an example. Mechanical energy storage examples include Flywheels, Pumped Hydro, and Compressed Air Energy Storage systems.

The study effort is agnostic to energy storage technology type and focuses primarily on the requirements of the ESS to interconnect on the PSE transmission system.

An example of a deployed Energy Storage System (located in South Australia) is shown in Figure 1.1. This is presently the world's largest ESS that uses Lithium-Ion batteries. The purpose of introducing this project is to give a sense of relative scale associated with a high energy capacity/high power ESS.

Figure 1.1 Hornsdale Power Reserve ESS



2. Methodology

Two methodologies were employed for this study. A qualitative and a quantitative method.

The qualitative method is a high-level review to determine potential for interconnection at the substation and to determine the potential to site an ESS in the area (PSE's property is not available for siting the ESS for this analysis). If a substation meets the evaluation metrics (detailed below) for the qualitative method, the locations will be further studied with the quantitative method.

The quantitative method is a high-level power flow analysis of the PSE transmission system, using official WECC databases to review the system performance with the addition of an ESS during charging and discharging conditions, for a multitude of system conditions and system contingencies.

These details of the qualitative and quantitative methods are discussed in the relevant section below.

2.1. Qualitative Method

Overhead imagery was utilized to determine the location of Puget's substations. This imagery was analysed in conjunction with WECC base cases and FERC 715 filings (pre-2001) that contain one-line drawings of the Puget system. We note that prior to October 2001 FERC 75 filings were available to the public. The stations were geo-located, mapped, locations were populated in the power flow-based cases, and then substations were created in the power flow base cases in order to support more detailed analysis using modelling and simulation tools.

2.1.1. Substation Interconnection Suitability

PSC examined the candidate substations to determine their suitability for expansion to accommodate interconnection of an ESS to the substation. This study assumes the ESS is sited off of PSE land in the area near the substation. Evaluation metrics are as below:

- Must interconnect to an existing Puget station
- Interconnects to PSE "native" network west of Cascades, no wheeling
- No radial or "return loop" transmission
- Above >100 kV point of interconnection (POI) per following details:
  - At least 4 lines for 115 kV candidate stations
  - Or non-radial 230 kV station
- Expansion space "in-the-gravel" in the station exists
- Development potential of existing station for interconnection is evident
  - Open space is desirable
  - Heavy residential presence is not desirable
  - Must pass the "Good Neighbor" test, which from an electric utility perspective has the following attributes:
    - Use of eminent domain proceedings is the absolute last resort with condemnation only used for those projects that are extremely mission critical and are supported politically.
    - The minimal number of landowners are impacted by a project and those landowners are justly compensated at prevailing rates.
    - Projects are developed with a focus on maximizing the use of existing "encumbered" properties.

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        - Land use should be reasonably consistent with its present use and the addition of electric utility infrastructure should be designed to be as unnoticeable as possible
        - Early involvement of the public in the development process is a must and the public should be encouraged to provide constructive input and alternative projects/locations
        - The public knows their neighbourhood best and can suggest minimum impact alternatives
        - Successful "Good Neighbor" projects leave the affected area better than it was before the project was executed.
- Identify substation configuration allows for additional breaker position
    - Ring bus, breaker and a half, double bus double breaker is preferred.
    - Main bus (with aux bus) has questionable reliability and could result in additional upgrades, up to rebuilding the substation to a different configuration.
    - Main bus (without aux bus) has poor reliability and is not suitable for interconnection of an ESS and would require substation upgrades, up to rebuilding the substation to a different configuration
        - An internal failure of a circuit breaker causes loss of entire station
- Identify existing unused breaker position (breaker not installed)
- Identify if the substation area allows for expansion
    - Examine available space inside substation fence
    - Examine available space outside substation fence
- If substation has 115 kV and 230 kV voltages, preference should be given to interconnect at the 115-kV side, unless interconnection at 230 kV results in substantial benefits.

2.1.2. ESS Siting Suitability

PSC examined how practical ESS siting near the substation is. This examination included:

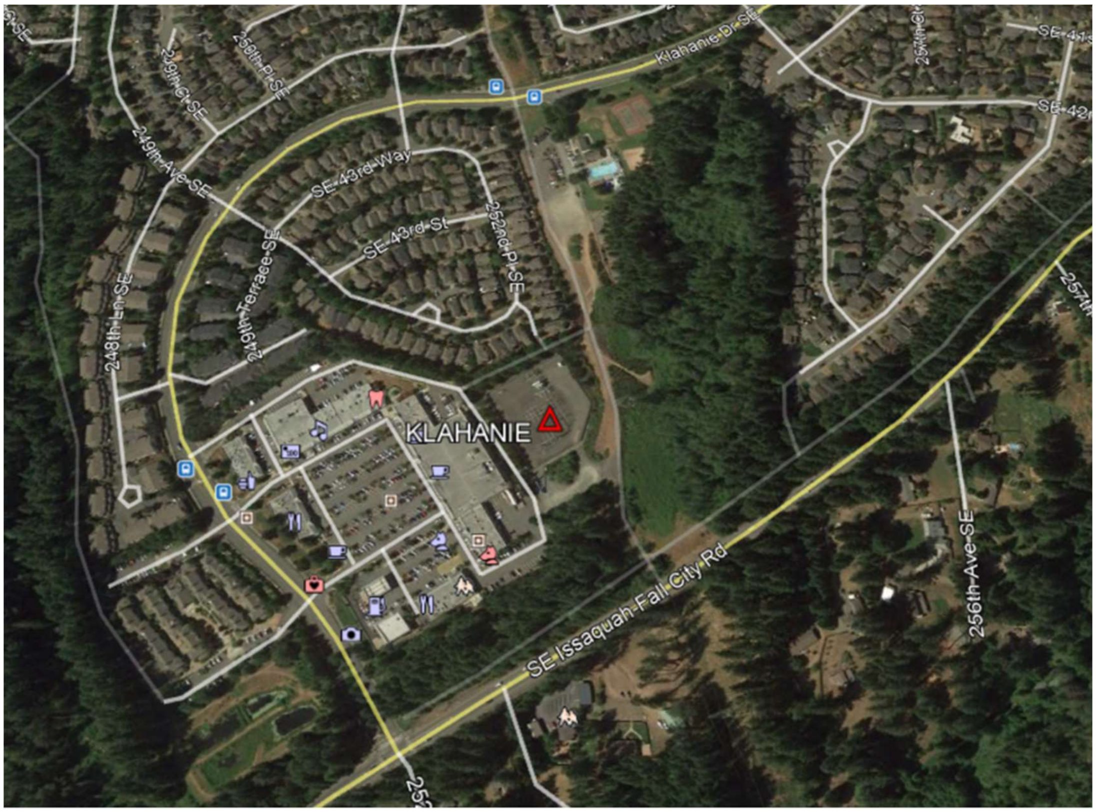
- Land use and Zoning compatibility
    - Imagery analysis and general land usage was examined using tools such as Google Earth and Land Grid. These tools provide a means to develop a general qualitative sense of how favourable the location near a particular PSE station might be for an ESS project.
    - Highly residential areas, constraints for possible transmission rights-of-ways to the PSE station, schools, hospitals, and other notable land uses indicate that that specific PSE station was less desirable as a practical location to interconnect an ESS.
- Environmental Constraints
    - Overhead imagery analysis was performed in order to identify the possibility of complicated environmental constraints.
        - For example, the PSE Snoqualmie Falls station met the basic requirements of electrical connectivity but clearly it is not a desirable location for additional development. Thus, that station was not a candidate for further analysis.

2.2. Qualitative Method - Example

Two examples of qualitative review (i.e., go or no-go) of candidate stations are briefly discussed as follows.

The Klahanie station (Figure 2.1) would be characterized as a high “risk” or red station. The Klahanie station is not desirable for an ESS interconnection due to its lack of space, residential encroachment, and general lack of development potential.

Figure 2.1 Undesirable Station: Klahanie



The Alderton station (Figure 2.2) is an example of a low “risk” (i.e., green station) that has desirable attributes associated with the station such as:

- Space for development in the immediate area
- Space in the station for expansion
- Fairly rural area that might be more easily support new rights-of-way, station expansion, or ESs siting

Figure 2.2 Desirable Station: Alderton

2.3. Quantitative Method

PSC used WECC power flow base cases to examine the PSE transmission system for the list of substations feasible for ESS interconnection. PSC used the PowerWorld (version 21) power flow ATC tool to perform analysis that approximates a “light-weight” generation interconnection feasibility screening study. This study is not a feasibility study under the OATT, but rather an informational screening that could aid an RFP respondent in determining where to queue for a detailed LGIA interconnection request. These POI’s were examined as charging (load) and discharging (generating) resources.

- Study Cases (WECC PowerWorld *.pwb power flow cases):
  - 2029-2030 Heavy Winter
    - Case used was 30HW1a1.pwb
  - 2030 Heavy Summer
    - Case used was 30HS1a.pwb
    - A 2029 HS case was originally used but then rejected due to an incomplete PSE transmission project that caused contingency performance issues (29HS1a1.pwb)
  - Off-peak load case (at consultants' discretion) which was the 2030 Light Spring case (30LSP1Sa.pwb)
- ESS studied as generation (discharging) and also as a load (charging)
  - ESS was studied one at a time
    - No groups or combinations of ESS's were studied
    - Only single ESS's were studied
- Only one interconnection per site location (either 115 kV or 230 kV, not both)
- Determine maximum ESS size at each location that results in acceptable system performance, for NERC TPL-001-4 PSE P0, P1 (N-1), and P6 (N-1-1) contingencies, while studying limited and sensitive neighbouring contingencies.

2.3.1. Quantitative Software Use and Approach

The results of the qualitative analysis and study were obtained using the "ATC" tool of PowerWorld Simulator. The details for implementing this in PowerWorld are briefly described as follows:

- Create an ALL WECC injection group of generators to dispatch against
  - The following metrics were used to select generators:
    - Pmax>10 MW
    - Pgen>10 MW
    - Pmin>0
  - ALL WECC injection group metrics (from 30HS case)
    - Number of generators is 2272
    - Total MW injection is ~191,294 MW
- Insert a single ESS (i.e. generator) and create an injection group for each station in Table 3.1
- Create an auto-inserted list of contingencies for Area 40
- Performed "Iterated Linear then Full Ctg" ATC analysis
  - Ignore elements with OTDFs < 3.0
  - Ignore elements with PTDFs<3.0
  - Report only:
    - 20 Transfer Limiters
    - 3 Limiters per ctg
    - 3 Limiters per element
- The results were manually inspected and those limiting elements and/or contingencies that were not relevant to the ESS were ignored for further analysis.
  - One may view this as machine aided learning to determine those contingencies and electrical system elements that are truly associated with electrical service to the ESS sites.
    - Many of these ignored elements/contingencies were 500 kV elements/contingencies with remedial action schemes or near their limits in the base case (for example various series capacitors associated with the California Oregon Intertie, etc).

- The metrics associated with the quantitative analysis are noted below:
  - All elements with valid ratings were scanned for performance with the ATC tool for PO, P1, and P6 conditions of the NERC TPL-001-4 standard
    - Summer Emergency ratings were RATEA
    - Winter Emergency ratings were RATEC
    - Spring Emergency ratings were RATEG
  - P1 & P6 contingencies were those in the Northwest >100 kV
    - P1: 1135 out of 5081 contingencies were examined for detailed P1 performance
      - The smaller list of contingencies was selected using the Linear ATC tool which determined those contingencies sensitive to the PSE BESS sites.
    - P6: 1107 out of 144,453 contingencies were examined for detailed P6 performance
      - The smaller list was tested for performance using the Iterated Linear feature of the ATC tool. The larger amount was screened with the linear ATC tool.

3. Results

The results of the qualitative and quantitative analysis are listed below.

3.1. Qualitative Results

The results of the qualitative analysis and study were obtained in an iterative fashion. The list of candidate stations was then inspected both in PowerWorld Simulator and with overhead imagery to cull undesirable locations. The results follow:

- 382 total PSE initial stations (based on software results).
  - The 382-station count may not be a figure that exactly matches the number of stations that PSE has. This is due to the software requirement for a tapped line to be modeled with a bus, which might not be representative of an actual substation bus.
  - These 382 stations were geo-located.
- 36 PSE stations were kept for overhead imagery analysis based on the following:
  - Is 230 kV non-radial service.
  - Or is > 4 lines of 115 kV non-radial service.
  - And within PSE network
    - Determined from geo-location and bus ownership
  - Substation configuration metrics were not included in determining of the initial candidate stations.
- The 36 PSE stations were analysed and grouped by the following criteria for risk regarding ESS site location and interconnection:
  - Substation area analysis
  - Surrounding area analysis
  - Refined understanding of interconnection based on imagery analysis
- 12 stations (of the 36) were assigned “green”, for initial low risk ESS interconnection
- 8 stations (of the 36) were assigned “yellow”, for initial medium risk ESS interconnection
- 16 stations (of the 36) were assigned “red”, for high risk due to not meeting the initial qualitative screening metrics

3.1.1. Candidate Stations

Table 3.1 lists the 20 PSE stations that were analyzed in detail. These stations were visually inspected with recent overhead imagery and are organized by color for low risk and medium risk substations. As previously stated, the substation configuration metrics were not used for the initial candidate stations and will be addressed later in the report. Substations that are of a main bus configuration are highlighted in red.

Table 3.1 Qualitative Results for Low Risk (Green) and Medium Risk (Yellow) Stations

Sub Name	Nominal kV Range	# of Lines	Bus Configuration (low & high voltage)	Zone
Alderton	115.0 (only)	7	Main & Aux	PIERCE
Berrydale	115.0 to 230.0	7	Main & Aux / Brk & half	S.KING
Christopher	115.0 (only)	6	Main Bus	S.KING
Frederickson	13.8 to 115.0	4	Main Bus	PIERCE
Fredonia	13.8 to 230.0 (115kV)	2	Main Bus	SKAGIT
Lake Tradition	115.0 (only)	8	Main Bus	N.KING
March Point	115.0 to 230.0	12	Main & Aux / Xfrm Term	SKAGIT
Midway	115.0 (only)	6	Main & Aux	S.KING
Saint Clair	115.0 to 230.0	7	Main & Aux / DB-DB	THURSTN
Sammamish	115.0 to 230.0	11	Main & Aux / Main & Aux	N.KING
Talbot Hill	115.0 to 230.0	14	Main & Aux / DB-DB	S.KING
Tono	115.0 (only)	4	Main & Aux	THURSTN
Bellingham	115.0 (only)	11	Brk & half	WHATCOM
Krain Corner	57.5 to 115	6	Main Bus	PIERCE
O'Brien	115.0 to 230.0	11	Main & Aux / Xfrm Term	S.KING
Portal Way	115.0 (only)	5	Main & Aux	WHATCOM
S. Bremerton	115.0 to 230.0	6	Main & Aux / Xfmr Term	KITSAP
Sedro Woolley	115.0 to 230.0	12	Main & Aux / Brk & half	SKAGIT
Starwood	115.0 (only)	4	Main Bus	S.KING
White River	115.0 to 230.0	12	Main & Aux / DB-DB	PIERCE

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Table 3.2 lists those stations that were deemed high risk and thus not selected for more detailed analysis.

Table 3.2 Qualitative Results for High Risk (Red) Stations

Sub Name	Nominal kV Range	# of Lines	Substation Type	Zone
ARCO C	115.0 (only)	4	Main Bus	WHATCOMI
BAKER SW	115.0 (only)	4	Main Bus	SKAGIT
BALDI	230.0 (only)	2	Tap	S.KING
CASCADE	34.5 to 230.0	3	Xfmr Term/Main Bus	KITTITAS
COTAGEBR	115.0 (only)	4	Main Bus	N.KING
ELECTHTS	57.5 to 115.0	5	Xfmr Term/Main Bus	PIERCE
HORSRNCH	230.0 (only)	3	Main Bus	N.KING
HRNCHTAP	230.0 (only)	2	Tap	N.KING
KLAHANIE	230.0 (only)	2	Tap	N.KING
LAKESIDE	115.0 (only)	7	Main Bus	N.KING
MINTFARM	13.8 to 230.0	1	Main (Gen Interconnection)	Portland Area
NOVELTYH	115.0 to 230.0	7	Main & Aux/Main Bus	N.KING
OLYMPA P	115.0 (only)	9	Main Bus	THURSTN
SHUFFLETON	115.0 (only)	4	Main & Aux	S.KING
SNOQ SW	2.0 to 115.0	5	Main Bus	N.KING
FREDONIA	13.8 to 115.0	4	Main Bus	SKAGIT

Note that there are two Fredonia stations, one serves a gas turbine power plant and the second serves local load. The “red” Fredonia station is the load serving station. Although these stations are “red” (or less desirable for ESS integration) they may be worthy of further review and analysis.

3.2. Quantitative Results

3.2.1. Quantitative Results

Table 3.3, 3.4, and 3.5 lists the results from the quantitative analysis. The gen/load limit is equivalent to the discharge/charge limit for the ESS at the listed station for TPL-001-4 P0, P1, and P6 conditions (for the most limiting element). Units for the limits are MW. Note that we omit the negative sign for load since the sign is implicit in the definition of load.

Results shown in the tables indicate the ESS sizes for the different substations on an individual bases, meaning the potential size for a single ESS to be placed at any one of the locations listed. The results are not meant to indicate that the ESS sizes listed can be installed for all locations simultaneously.

BPA 500 kV contingencies (such as the Raver-Paul 500 kV line loss) were noted, but not considered as limiting contingencies since it is known that these contingencies have remedial action schemes associated with them. BPA has historically planned its system for P1 outages and has not necessarily planned (and built) its system to perform for P6 outages (without operator action).

A 2030 Light Spring case was examined to test performance under P0, P1, and P6 conditions to determine if there was any notable sensitivity to light spring conditions (in addition to the Heavy Summer and Heavy Winter cases).

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Table 3.3 P0 Quantitative Results

Quantitative Results - P0 Results in MW (Green shaded stations are low risk; yellow shaded stations are medium risk)								
Substation	2030 Heavy Summer		2030 Heavy Winter		2030 Light Spring		Maximum ESS Size	
	Generating	Charging	Generating	Charging	Generating	Charging	Generating	Charging
Alderton	725	(790)	872	(823)	886	(998)	725	(790)
Berrydale	982	(248)	1077	(273)	1031	(569)	982	(248)
Christopher	751	(419)	1031	(648)	842	(622)	751	(419)
Frederickson	432	(316)	485	(440)	404	(466)	404	(316)
Fredonia	510	(803)	679	(873)	538	(878)	510	(803)
Lake Tradition	725	(534)	993	(701)	888	(837)	725	(534)
March Point	664	(367)	834	(367)	701	(412)	664	(367)
Midway	550	(263)	711	(333)	558	(368)	550	(263)
Saint Clair	520	(546)	756	(732)	810	(854)	520	(546)
Sammamish	409	(677)	517	(818)	546	(702)	409	(677)
Talbot Hill	754	(768)	935	(916)	834	(896)	754	(768)
Tono	755	(445)	567	(524)	548	(699)	548	(445)
Bellingham	695	(578)	1028	(894)	809	(1072)	695	(578)
Krain Corner	250	(222)	480	(351)	377	(308)	250	(222)
O'Brien	681	(554)	807	(694)	672	(627)	672	(554)
Portal Way	443	(565)	441	(772)	337	(740)	337	(565)
S. Bremerton	426	(328)	471	(341)	457	(420)	426	(328)
Sedro Woolley	779	(950)	935	(1134)	867	(995)	779	(950)
Starwood	573	(335)	693	(341)	637	(578)	573	(335)
White River	872	(802)	1029	(945)	955	(887)	872	(802)

Charging limits have a parenthetical ( ) used in order to clearly indicate that the number is a charging (i.e. load) value. The maximum ESS sized is determined by the maximum size that the ESS can operate for all cases. Therefore, the minimum value between the three seasonal cases determines the maximum ESS size for performance under P0 conditions.

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Table 3.4 P1 Quantitative Results

Quantitative Results – P1 Results in MW (Green shaded stations are low risk; yellow shaded stations are medium risk)								
Substation	2030 Heavy Summer		2030 Heavy Winter		2030 Light Spring		Maximum ESS Size	
	Generating	Charging	Generating	Charging	Generating	Charging	Generating	Charging
Alderton	96	(366)	510	(581)	529	(655)	96	(366)
Berrydale	756	(167)	848	(181)	702	(437)	702	(167)
Christopher	552	(217)	758	(362)	613	(386)	552	(217)
Frederickson	135	(96)	308	(314)	266	(388)	135	(96)
Fredonia	110	(532)	161	(619)	124	(585)	110	(532)
Lake Tradition	518	(136)	811	(425)	664	(545)	518	(136)
March Point	272	(214)	555	(189)	485	(271)	272	(189)
Midway	432	(164)	530	(207)	446	(262)	432	(164)
Saint Clair	45	(254)	239	(423)	311	(685)	45	(254)
Sammamish	323	(99)	411	(370)	495	(425)	323	(99)
Talbot Hill	552	(242)	741	(459)	688	(590)	552	(242)
Tono	437	(85)	275	(374)	282	(543)	275	(85)
Bellingham	322	(109)	545	(452)	384	(656)	322	(109)
Krain Corner	136	(34)	250	(88)	188	(112)	136	(34)
O'Brien	535	(258)	634	(276)	559	(401)	535	(258)
Portal Way	105	(446)	392	(628)	284	(614)	105	(446)
S. Bremerton	313	(89)	301	(27)	375	(185)	301	(27)
Sedro Woolley	287	(589)	577	(715)	450	(700)	287	(589)
Starwood	373	(181)	545	(250)	459	(299)	373	(181)
White River	583	(379)	838	(434)	715	(592)	583	(379)

Charging limits have a parenthetical ( ) used in order to clearly indicate that the number is a charging (i.e. load) value. The maximum ESS sized is determined by the maximum size that the ESS can operate for all cases. Therefore, the minimum value between the three seasonal cases determines the maximum ESS size for performance under P1 conditions.

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Table 3.5 P6 Quantitative Results

Quantitative Results – P6 Results in MW (Green shaded stations are low risk; yellow shaded stations are medium risk)								
Substation	2030 Heavy Summer		2030 Heavy Winter		2030 Light Spring		Maximum ESS Size	
	Generating	Charging	Generating	Charging	Generating	Charging	Generating	Charging
Alderton	134*	(76*)	448	(205)	324	(290)	134*	(76*)
Berrydale	515*	(52*)	847	(90)	707	(336)	515*	(52*)
Christopher	484*	(57*)	756	(337)	610	(386)	484*	(57*)
Frederickson	99*	(86*)	275	(284)	222	(389)	99*	(86*)
Fredonia	9*	(378)	101	(421)	69	(479)	9*	(378)
Lake Tradition	521*	(44*)	805	(387)	664	(545)	521*	(44*)
March Point	9*	(54)	201	(62)	172	(78)	9*	(54)
Midway	428*	(56*)	512	(121)	444	(218)	428*	(56*)
Saint Clair	39*	(412)	147	(528)	159	(633)	39*	(412)
Sammamish	323	(46*)	411	(370)	495	(445)	323	(46*)
Talbot Hill	450*	(48*)	622	(359)	833	(896)	450*	(48*)
Tono	592	(122*)	267	(339)	548	(698)	267	(122*)
Bellingham	10*	(108)	418	(67)	382	(657)	10*	(67)
Krain Corner	136*	(34*)	178	(4*)	188	(112)	136*	(4*)
O'Brien	520*	(54*)	225	(176*)	560	(521)	225	(54)
Portal Way	11*	(446)	185	(362)	298	(614)	11*	(362)
S. Bremerton	314	(89*)	79	(23*)	375	(185)	79	(23*)
Sedro Woolley	48*	(590)	519	(622)	447	(755)	48*	(590)
Starwood	370*	(13*)	240	(107*)	460	(311)	240	(13*)
White River	365*	(13*)	382	(121*)	714	(750)	365*	(13*)

Charging limits have a parenthetical ( ) used in order to clearly indicate that the number is a charging (i.e. load) value. The maximum ESS sized is determined by the maximum size that the ESS can operate for all cases. Therefore, the minimum value between the three seasonal cases determines the maximum ESS size for performance under P6 conditions. Those limits with an asterisk (*) indicate that a pre-existing limit was ignored, and the first non-zero ATC transfer limit was recorded for the ESS charging and discharging contingency-based limit.

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4. Analysis

A review of Table 3.2, Table 3.3, and Table 3.4, indicate to the user the following:

- A single ESS performs for both discharging (generator) and charging (load) depending upon the substation location
  - Between 248 MW – 802 MW under P0 conditions
  - Between 45 MW – 434 MW for P1 conditions
  - Between 9 MW – 122 MW for P6 conditions
- Summer ratings can be most limiting and generally (but not always) summer may be the defining season for limiting an ESS.
  - This is due to limits being thermally based and higher summer temperatures causing de-rating of thermally limited equipment.
- Pre-existing conditions exist that should be examined in greater detail if any of these ESS locations are considered for interconnection.
- Limitations exist for P6 summer operations
  - Note that for ESS limits indicated with an asterisk (*) in the tables indicate there pre-existing P6 issues may exist.
- Some P6 contingencies may, surprisingly, perform better than P1 contingencies
  - The reasons for this are complex but, in many cases, the P1 limiting element is removed from service by the P6 contingency and thus a higher limiting element is relevant.

Table 4.1 shows the results for each substation on a contingency category bases, and also shows the maximum size for the ESS when generating or charging. Similarly, to before, the maximum size is the minimum value across the three contingency categories (i.e. P0, P1, and P6).

Further, the table shows the Total Maximum size of the ESS. The Total Maximum size is the minimum value (absolute) between the generating and charging values and represents the maximum size of the ESS that allows for unconstrained use during varying seasonal load conditions, varying operating conditions, and varying contingencies. The Total Maximum size is the value used to show the potential ESS size that might be achieved for NRIS while limiting the risk of additional costly network upgrades (transmission line rebuilds / reconductoring, etc.) outside of those required for interconnection to the substation.

The Operational Agreements determined with the developer could increase the Total Maximum size beyond the P6 charging limitations of the ESS listed in the table below.

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Table 4.1 Combined Quantitative Results

Substation	Substation Type	P0 Results		P1 Results		P6 Results		Maximum ESS		Total Maximum
		Generating	Charging	Generating	Charging	Generating	Charging	Generating	Charging	
Alderton	Main & Aux	725	(790)	96	(366)	134*	(76*)	96	(76*)	76*
Berrydale	Main & Aux	982	(248)	702	(167)	515*	(52*)	515*	(52*)	52*
Christopher	Main Bus	751	(419)	552	(217)	484*	(57*)	484*	(57*)	57*
Frederickson	Main Bus	404	(316)	135	(96)	99*	(86*)	99*	(86*)	86*
Fredonia	Main Bus	510	(803)	110	(532)	9*	(378)	9*	(378)	9*
Lake Tradition	Main Bus	725	(534)	518	(136)	521*	(44*)	518	(44*)	44*
March Point	Main & Aux	664	(367)	272	(189)	9*	(54)	9*	(54)	9*
Midway	Main & Aux	550	(263)	432	(164)	428*	(56*)	428*	(56*)	56*
Saint Clair	Main & Aux	520	(546)	45	(254)	39*	(412)	39*	(254)	39*
Sammamish	Main & Aux	409	(677)	323	(99)	323	(46*)	323	(46*)	46*
Talbot Hill	Main & Aux	754	(768)	552	(242)	450*	(48*)	450*	(48*)	48*
Tono	Main & Aux	548	(445)	275	(85)	267	(122*)	267	(85)	85
Bellingham	Brk & half	695	(578)	322	(109)	10*	(67)	10*	(67)	10*
Krain Corner	Main Bus	250	(222)	136	(34)	136*	(4*)	136*	(4*)	4*
O'Brien	Main & Aux	672	(554)	535	(258)	225	(54*)	225	(54*)	54*
Portal Way	Main & Aux	337	(565)	105	(446)	11*	(362)	11*	(362)	11*
S. Bremerton	Main & Aux	426	(328)	301	(27)	79	(23*)	79	(23*)	23*
Sedro Woolley	Main & Aux	779	(950)	287	(589)	48*	(590)	48*	(589)	48*
Starwood	Main Bus	573	(335)	373	(181)	240	(13*)	240	(13*)	13*
White River	Main & Aux	872	(802)	583	(379)	365*	(13*)	365*	(13)	13*

Those limits with an asterisk (*) indicate that a pre-existing limit was ignored, and the first non-zero ATC transfer limit was recorded for the ESS charging and discharging contingency-based limit. As stated above, the Operational Agreements determined with the developer could increase the Total Maximum size beyond the P6 charging limitations of the ESS.

Table 4.2 shows a summary of the results for this effort. The table provides the reader with a convenient listing of the Total Maximum ESS output and the location of the electrical point of interconnection studied, as well as substation type, and operating voltage.

Table 4.2 Location Summary with Maximum ESS Results

Substation	Substation Type	Voltage (kV)	Location		Total Maximum ESS (MW)
			Latitude	Longitude	
Alderton	Main & Aux	115	47.15344	-122.2365	76
Berrydale	Main & Aux	115	47.37803	-122.1311	52
Christopher	Main Bus	115	47.33708	-122.2393	57
Frederickson	Main Bus	115	47.08061	-122.3647	86
Fredonia	Main Bus	115	48.45461	-122.4371	9
Lake Tradition	Main Bus	115	47.53069	-122.0117	44
March Point	Main & Aux	115	48.45714	-122.5625	9
Midway	Main & Aux	115	47.40239	-122.2944	56
Saint Clair	Main & Aux	115	47.03511	-122.7356	39
Sammamish	Main & Aux	115	47.68558	-122.1499	46
Talbot Hill	Main & Aux	115	47.46864	-122.191	48
Tono	Main & Aux	115	46.75539	-122.8775	85
Bellingham	Brk & half	115	48.75939	-122.4604	10
Krain Corner	Main Bus	115	47.23511	-121.9855	4
O’Brien	Main & Aux	115	47.40317	-122.2432	54
Portal Way	Main & Aux	115	48.90361	-122.63	11
S. Bremerton	Main & Aux	115	47.53764	-122.6914	23
Sedro Woolley	Main & Aux	115	48.50458	-122.204	48
Starwood	Main Bus	115	47.29039	-122.3623	13
White River	Main & Aux	115	47.239	-122.2096	13

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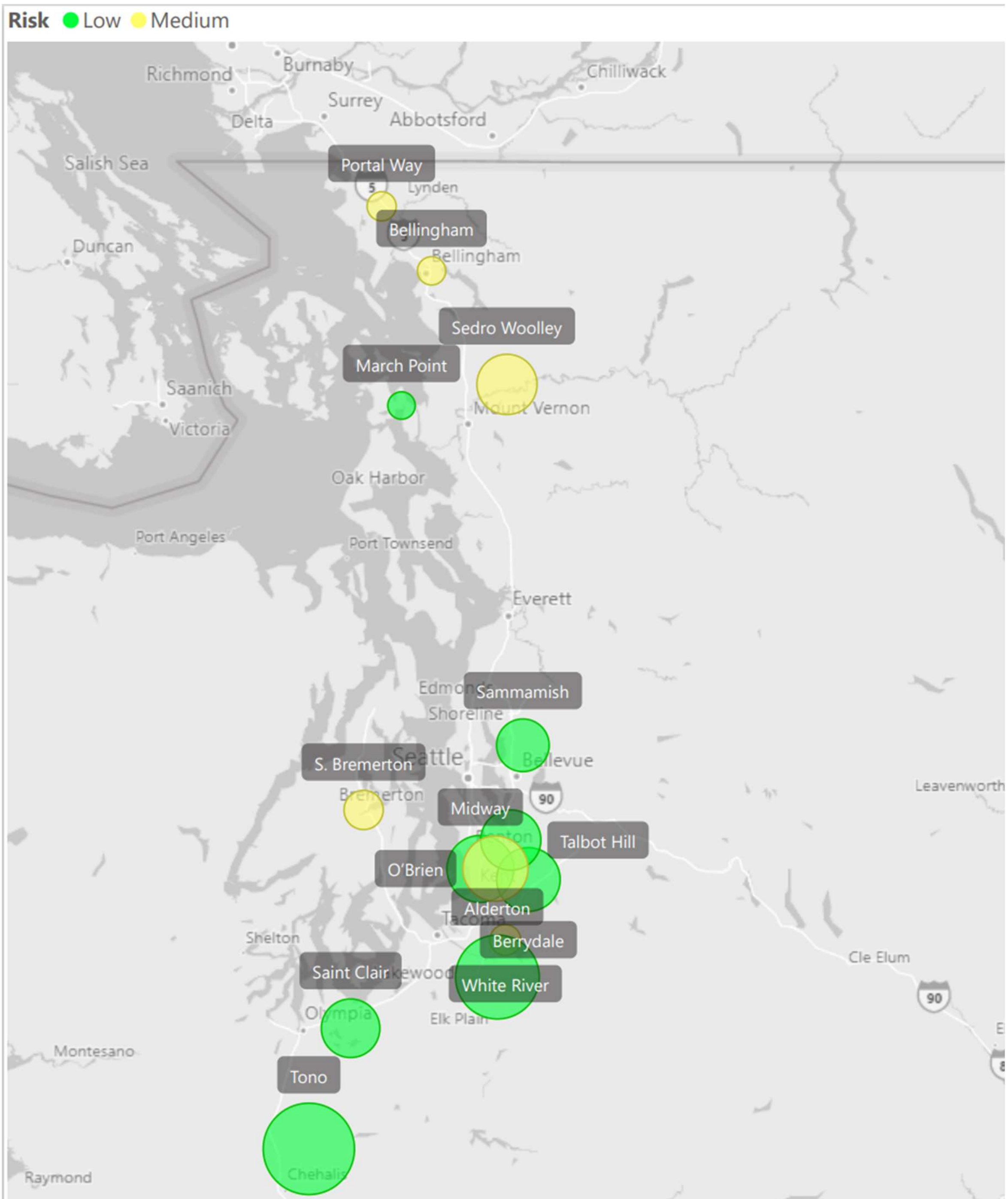
As discussed previously, the main bus substation configuration (without an aux bus) has questionable reliability and interconnecting at a main bus substation has the potential to result in the need for high network costs to rebuild the substation. The substations that are configured with just a main bus (with no aux bus) were removed from the results to create the final results table as shown in Table 4.3. The table provides the reader with a convenient listing of the Maximum ESS output and the location of the electrical point of interconnection studied, as well as substation type, and operating voltage.

Table 4.3 Final Results Table

Substation	Substation Type	Voltage (kV)	Location		Total Maximum ESS (MW)
			Latitude	Longitude	
Alderton	Main & Aux	115	47.15344	-122.2365	76
Berrydale	Main & Aux	115	47.37803	-122.1311	52
March Point	Main & Aux	115	48.45714	-122.5625	9
Midway	Main & Aux	115	47.40239	-122.2944	56
Saint Clair	Main & Aux	115	47.03511	-122.7356	39
Sammamish	Main & Aux	115	47.68558	-122.1499	46
Talbot Hill	Main & Aux	115	47.46864	-122.191	48
Tono	Main & Aux	115	46.75539	-122.8775	85
Bellingham	Brk & half	115	48.75939	-122.4604	10
O’Brien	Main & Aux	115	47.40317	-122.2432	54
Portal Way	Main & Aux	115	48.90361	-122.63	11
S. Bremerton	Main & Aux	115	47.53764	-122.6914	23
Sedro Woolley	Main & Aux	115	48.50458	-122.204	48
White River	Main & Aux	115	47.239	-122.2096	13

Figure 4.1 gives an approximate location of the substations with low and medium risk for interconnection. The figure shows that there are many opportunities throughout the native PSE system for interconnecting an ESS.

Figure 4.1 Location of Selected Stations



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5. Conclusions and Recommendations

PSC believes that opportunities exist for Puget Sound Energy to install Energy Storage Systems in several stations without undue impact (or required network upgrades) to the surrounding electrical transmission system. We base this conclusion of performance under P6 outages during heavy summer and winter peak load conditions, as required for Network Resource Interconnection Service for use as a capacity resource on PSE’s transmission system.

As previously stated, the results of this effort are to be used to help guide proponents to locations (with approximate capacities) that might offer success for interconnection of an ESS for NRIS with limited network upgrades. The formal LGIA process, as detailed under the Puget Sound Energy FERC Open Access Transmission Tariff (OATT), will define required system interconnection upgrades and any potential network upgrades as a result of the more detailed studies (power flow and transient), impacts of projects already in the interconnection que, affected neighbouring transmission providers, and short circuit analysis.

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