Puget Sound Energy

DERs and Grid Reliability

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PUGET SOUND ENERGY

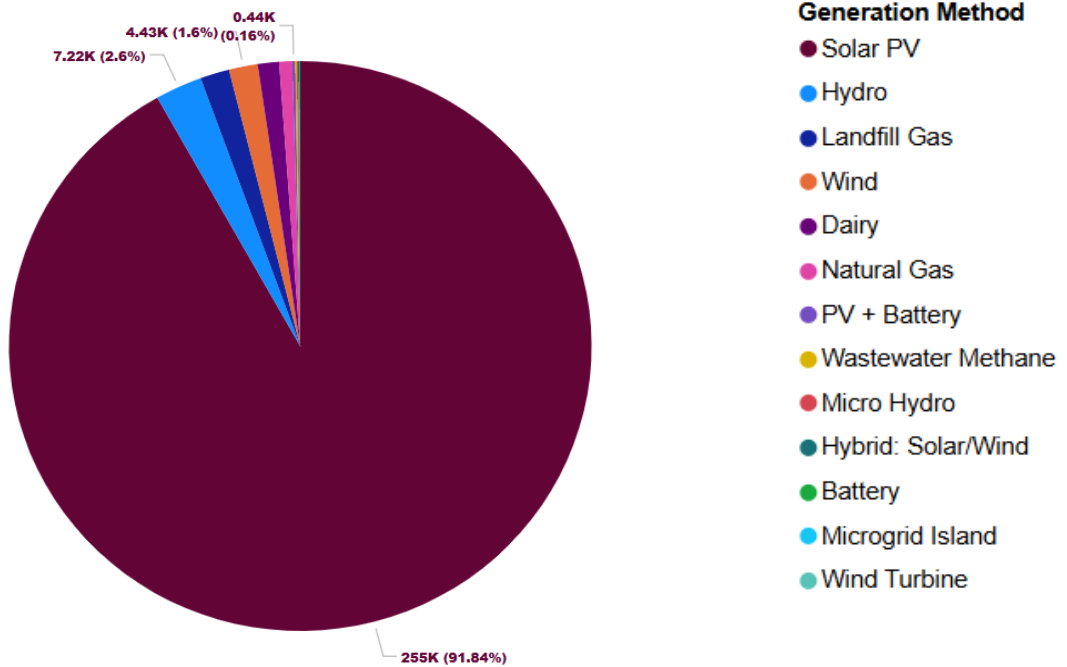
PSE's service territory and Customer Generators

- PSE has 1.5 million customers, ten counties and 6,000 square miles of service territory
  - 28,000 are net metered customers
  - 162 customers are interconnected through DER Portal

DER & NEM Systems on PSE Distribution System

Generation Method	Sum of Max Output Capacity kW AC
NEM Solar	232,820
NEM Battery	25,553
DER Solar	22,923
DER Hydro	7,220
Landfill Gas	4,500
DER Wind	4,350
DER Dairy	3,285
Natural Gas	2,000
DER Battery	1,606
DER PV+BESS	437
Wastewater Methane	250
Micro Hydro	234
NEM Hybrid Solar/ Wind	173
NEM Wind	75
Microgrid Island	50

Output kW AC by Method of Generation



Breaking down DERs into Generation Capacity

- Inverter based systems are broken down into Tiers 1-3 to determine protection schemes and requirements based on Technical Interconnection and Interoperability Requirements (TIIR).

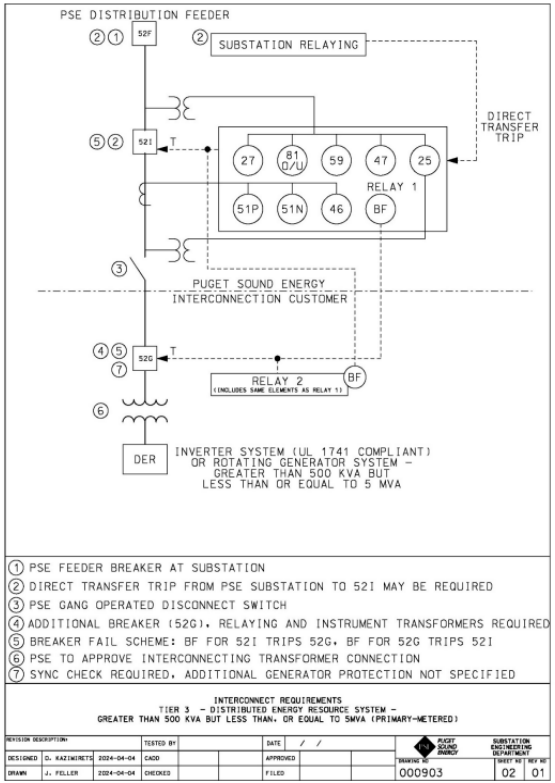
5.4 TYPICAL INTERCONNECTION REQUIREMENTS

Table 5.1 Summary of Interconnection One-Line Diagrams

For AGGREGATE Generation Capacity:	See:
Tier 1 - Inverter Based Systems Less Than or Equal to 25 kW	Drawing 000901-01
Tier 2 - Inverter Based Systems Greater Than 25 kW but Less Than or Equal to 500 kW	Drawing 000902-01
Tier 2 - Non Inverter Based Systems Less Than or Equal to 500 kW	Drawing 000904-01
Tier 3 - DER System Greater Than 500 kW but Less Than or Equal to 5 MW (Secondary-Metered)	Drawing 000903-01
Tier 3 - DER System Greater Than 500 kW but Less Than or Equal to 5 MW (Primary-Metered)	Drawing 000903-02
Tier 3 - DER System Greater Than or Equal to 5 MW but Less Than or Equal to 10 MW	Drawings 000906-01 & 000906-02
Metering - Option A	Drawing 90701
Metering - Option B	Drawing 90801

Note: Aggregate generation includes all existing and proposed generation.

Tier 3 - DER System Greater Than 500 kW but Less Than or Equal to 5 MW (Primary-Metered)



Protection requirements based on generation capacity and type

Tier	Size	Meter	Generation Type	Interconnection Protective Device	Interconnection Protective Relay	Interconnection Protective Elements	Substation Protective Elements	Direct Transfer Trip Scheme
1	≤25kVA	Secondary	IBR †	Inverter	-	-	-	-
2	>25kVA ≤500kVA	Secondary	IBR †	Inverter	-	-	-	-
			IBR with BESS (Microgrid) †	Circuit Breaker -or- Fuse w/ Contactor	Single Microprocessor Relay	25, 27, 59, 81, Relay Fail		
			Rotating Machine (Non-synchronous)			25, 27, 51, 51V, 59, 81, Breaker Fail, Relay Fail		
3	>500kVA <2MVA	Secondary	IBR †	2 Circuit Breakers	Redundant Microprocessor Relays	25, 27 ,32, 46, 47, 51, 51V, 59, 59G, 81, Breaker Fail, Relay Fail	(27, 59, 59Q, 59G) ††	May be Required**
			Rotating Machine					
	≥2MVA <10MVA	Primary	IBR †	2 Reclosers				
			Rotating Machine					

* Substation Line-Side PT and HBDL scheme may be required based on circuit load conditions

** DTT required for interconnections with generation larger than 50% minimum circuit load - Determined by System Planning

† Inverters must possess UL1741-SB certification

†† Substation protection elements required for interconnections with generation larger than 50% substation bank load

Inadvertent Export of Energy to the Grid

Anti-Islanding & Fault Detection

UL1741-SB Inverters for IBRs

- UL1741-SB implements IEEE1547

IEEE1547 Ride-Through and Anti-Islanding

- Under/over voltage (27/59)
- Under/over frequency (81U/O)

Direct Transfer Trip (DTT)

- Required when DER generation exceeds 50% minimum distribution circuit load

Additional Protective Elements

- Sync check (25)

Protective Elements Specific to Rotating Machines

- Time overcurrent (51)
- Reverse-phase current (46)
- Phase-sequence voltage (47)
- Voltage restrained time overcurrent (51V)
- Ground overvoltage (59G)
- Negative sequence overvoltage (59Q)

Limit DER Power Export

Protective Element

- Directional power (32)
  - Trip DER if the power export limit agreement is exceeded

Alternative methods for addressing unintentional islanding

VTHD (Voltage Total Harmonic Distortion)

- Total harmonic distortion can increase during islanded conditions
- VTHD allows local detection of islanded conditions by analyzing harmonic distortion
- DER protective relays can use VTHD in lieu of a DTT scheme or during a lapse in communication between protective equipment

Synchrophasor Based Anti-Islanding

- Synchrophasors can be used to monitor and detect frequency deviations between two or more points in an electric system
- Allows detection of broken conductors between DER and utility source
- Can detect islanded conditions if DTT fails or there is a lapse in communication between DTT equipment

Vehicle to Grid Technologies and Standards

PSE takes a methodical approach to creating technology standards:

- **Start small:** We use pilot demonstrations as the building blocks for our standards
- **Build on proven frameworks:** Key industry standards shape our approach
  - IEEE 1547 helps us understand how inverters behave on the grid
  - IEEE 2030.5, 2030.7, 2030.8, and OpenADR ensure different systems can work together
- **Test thoroughly:** Our demonstrations allow us to verify that inverters work as expected and set performance targets for different applications
- **Integrate strategically:** Our Virtual Power Plant platform (edge-DERMS) can combine multiple technologies like Vehicle-to-Grid into a unified system
- **Evolve continuously:** We're moving toward standards that support two-way, controllable energy resources

This systematic process helps PSE introduce new technologies safely while keeping the grid stable and reliable.

Vehicle to Grid in Action

- Currently have two Pilot Projects with one commissioned this month in Olympia, WA
- Created technical specifications which include safety requirements, testing procedures and interconnection standards for all V2X applications (V2G, V2H, V2B). Collaborated with:
  - System Protection
  - System Planning
  - Meter Engineering
  - Meter Operations
  - System Operations
  - Real Estate
  - AHJ
  - Power Quality

Component	V2H Requirements	V2B Requirements	V2G Requirements
DC Output Protection	Trip at 110% rated (residential)	Trip at 125% rated (commercial)	Trip at 125% rated (utility)
Input Surge Protection	Type 2 SPD (residential)	Type 1+2 SPD (commercial)	Utility-grade coordination
Cable Temperature	90°C max (residential cable)	105°C max (commercial cable)	105°C max (utility cable)
Connector Position	No power if disconnected	No power if disconnected	No power if disconnected
Insulation Monitoring	>50 kΩ (residential)	>100 kΩ (commercial)	>100 kΩ (utility)

Table 1. Grid Protection Requirements

Questions?