Utility Benchmarking of Fast Trip Schemes and Relay Technologies for Fire Mitigation

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Summary

PG&E developed Enhanced Powerline Safety Settings (EPSS) to help reduce wildfire risk by adjusting the sensitivity and speed of protective devices such as circuit breaker relays and reclosers. As currently implemented, circuits enabled with EPSS are configured to clear bolted fault conditions at 100ms.

PG&E's Distribution Asset Planning Department requested Applied Technology Services (ATS) to contact other utilities and discuss their philosophies for reducing wildfire ignitions using protective device setting changes similar to PG&E's EPSS initiative.

The purpose of these discussions is to provide insight into what types of protective device setting changes other west coast utilities, with similar wildfire risks to PG&E, are implementing to mitigate the risk of wildfire ignitions from utility equipment. Previous discussions were limited to other large California utilities such as SCE and SDG&E. These discussions expanded to include several other utilities in Washington State, Oregon and British Columbia.

These discussions indicate that many other utilities have implemented fast trip settings for several years. SDG&E has had some form of fast trip settings for about 10 years, SCE started implementing their fast trip schemes in 2018, and Avista has had fast trip settings for several years. PacifiCorp performed there first systemwide implementation in 2021. BC Hydro has only performed testing and a limited pilot on one distribution circuit.

Other utilities are also looking at new technologies to detect high impedance faults, detecting falling or broken conductors and sensitive ground settings. SDG&E has implemented Sensitive Ground Fault (SGF) and High Impedance Fault detection settings on their system. Most other of these are in the testing or pilot phase in evaluating these new technologies.

Table 1: Utility Comparison: Service Area, Voltages, and configuration

	PG&E	SCE	SDG&E	PacifiCorp (for CA)	Avista	BC Hydro
Location	Northern & Central California	Southern & Central California	Southern California	Northern California, Oregon, Washington	Eastern Washington, N. Idaho	BC Canada
Customers	5,200,000	5,000,000	1,400,000	47,000	400,000	1,800,000
Service Area (sq. mi)	70,000	50,000	4,100	11,000	30,000	340,000
Total Dist. Subs	651	900	134	47	131	260
Total Dist. Circuits	3,074	4,600	1,035	NA	350	1,670
Total Dist Circuit-Miles	108,000	69,800	17,085	3000	19,100	34,333
UG Circuit-Miles	27,000	31,000	10,558	600	Mostly OH	Mostly OH
OH Circuit-Miles	81,000	38,800	6,527	2400	Mostly OH	Mostly OH
Circuits in HFTD	800	1,074	70	21	154	NA
Voltages (kV)	21, 12, 17, 4	33, 16, 12, 4	12, 4	4.2-20.8	13.2, 24, 34	12, 25
Config./Grounding	3-wire uni-ground, 4-wire multi-ground	3-wire uni-ground, 4-wire multi-ground	3-wire uni-ground, 3-wire multi-ground via line-installed ground banks, 4-wire multi-ground	3 wire delta, 3 wire uni-ground, 4 wire wye	4-wire multi-ground	4-wire multi-ground

Table 2: Utility Comparison: Fast Trip Settings Comparison

	PG&E	SCE	SDG&E	PacifiCorp (for CA)	Avista	BC Hydro
Fast Trip	Yes	Yes	Yes	Yes	Yes	Testing & Pilot
Fast Trip Designation	Enhanced Powerline Safety Settings (EPSS)	Fast Curve (FC) Settings	Sensitive Relay Profile (SRP)	Sophisticated Program Control Settings (SPCS)	Dry Land Mode (DLM)	NA
Year in Service	2021	2018	~2010	2021	2021	NA
Operating Mode(s)	1	1	4	2	3	1
Settings Applied:	Circuit Specific	Circuit Specific	Circuit Specific	Circuit Specific	Circuit Specific	Circuit Specific
Schedule	Daily (was seasonal in 2021)	Daily and Seasonal	Daily	Daily	Daily	Season
Fuse Over-reach (upstream 3-ph ganged trip operation for back feed prevention)	Yes	Typically No (potential use in limited cases)	Yes	Unsure	Yes	None
Activation Methods	Manual & Remote	Mostly Remote	Mostly Remote	Mostly Manual	Mostly Remote	Manual
Trigger	Weather Conditions, circuit and fire risk designation	Weather and Fuel Conditions	Extreme Fire Potential Index (FPI) or PSPS Forecasted	Weather Conditions	Fire Risk Potential Score (Risk =Prob. x Impact)	Weather Conditions

	PG&E	SCE	SDG&E	PacifiCorp (for CA)	Avista	BC Hydro
Settings Description	Set phase and ground instantaneous pickups to see EOL for fused taps within the device protective zone (DPZ).Set definite time with delay not to exceed 0.1 seconds and use 0.02-second margin for coordinating between devices.	Used multiples of normal minimum trip to set fast curve settings with a time delay of typically 2 cycles. These settings typically help coordinate with other line protection devices, including fuses, while balancing ignition risk. SCE currently is using more sensitive multiple of pickup settings with a time delay of 4 cycles at a circuit-specific level. All reclosing is blocked while fast curve settings are enabled	Phase elements are set to trip at a minimum of 50% above peak historical load. Ground elements are based on peak historical trends and set utilizing a specific table contained within the settings methodology. Set definite time with 0.5-cycle delay. Multiple devices set with SRP may operate for downstream faults due to sensitivity and reduced protection margins.	The settings profiles include (but are not limited to): Normal (fuse saving application): Instantaneous trip followed by reclosing attempts with time-overcurrent trips. Elevated risk, no line reclosers, fuses on the line: Substation breaker will have an instantaneous trip followed by single reclose attempt after sufficient time to limit the persistence of fire. Elevated risk, line reclosers: Substation breaker will have instantaneous trip with no reclose attempt. Extreme risk, no line reclosers, fuses on line: Substation breaker will have instantaneous trip with no reclose attempt. Safety hold: for line worker usage during line operations where no reclosing occurs.	The settings profiles include: -Underreach 50: Stops short of downstream DLM recloser. No Dly -Overreach 50: Reaches to end of fused taps of rly zone. Bkr Coordinated Dly -51: fuse coordinated -Per/phase Inrush Blk -Base Dry Land Mode: Trip on 50 element, single reclose, trip on 51 (50s disabled) - Reduces fire risk by fast trip of temp faults. Perm faults fuse coordinate (Base DLM used for lower fire risk) -Fire 2-Shot: Trip on 50, reclose, trip on 50 (F2S for elev fire risk) -Fire 1-Shot: Trip on 50 with no reclosing (F1S for high fire risk)	Fast Trip tested in one area using Siemens Fuse Savers (FS). Similar to Hot Line tag settings, used for worker safety: 50ms Phase, 500 ms Ground (less false trips, better coord.). Also Implemented single shot lockout

Table 3: Utility Comparison: Other Technologies being evaluated or in service

	PG&E	SCE	SDG&E	PacifiCorp (for CA)	Avista	BC Hydro
Sensitive Ground Fault (SGF) Detection Schemes	In service, thresholds set at 15 Amp, 15 sec	Generally, none; however, SCE has several dozen stations in service with impedance grounding to limit ground faults to less than 150 amps (low ground) or 50 amps (sensitive ground) where sensitive ground relay settings are applied	In service year-round. Set by evaluating peak neutral imbalance current on specific line section to set the SGF setting. SGF settings reviewed once per year for each device or when device operates in the field.	None	None	None
High Impedance Fault (HIF) or Down Conductor Detection (DCD) Schemes	Testing, Pilot	Pilot, in monitor/alarm mode only. Under specific circumstances, they apply these setting modes on line reclosers as part of their normal settings	In service since 2011	Pilot, enabled in monitoring mode only	Plan to deploy to reclosers on trouble ckts meeting min load required by HIF algorithm	None
Falling Conductor & Open Phase Detection	AMI Voltage Detection	AMI Voltage Detection, piloting Open Phase Detection	AMI Voltage Detection, Pilot on several feeders with falling wires scheme (voltage synchrophasor based system)	None	None	None

Utility Discussion Summaries

San Diego Gas & Electric (SDG&E)

SDG&E operates an electric distribution system that serves approximately 3.6 million people through about 1.4 million meters. SDG&E's service territory spans more than 4,100 square miles from the California-Mexico border north to Southern Orange County and Riverside County and from the San Diego County Coastline east to Imperial County. SDG&E's system includes 134 distribution substations, 1,035 distribution circuits, 225,697 poles, 10,558 circuit miles of underground systems and 6,527 circuit miles of overhead systems. Approximately 3,500 circuit miles of overhead circuits are operated within the High Fire Threat District (HFTD). The electric distribution system consists of predominantly underground facilities (62%), but significant overhead facilities span the high-risk fire areas. The primary distribution voltage is mostly 12 kV, with some large areas of 4 kV. Grounding configurations for the distribution system include 3-wire uni-grounded, 3-wire multi-grounded via line-installed ground banks and a 4-wire multi-grounded configuration.

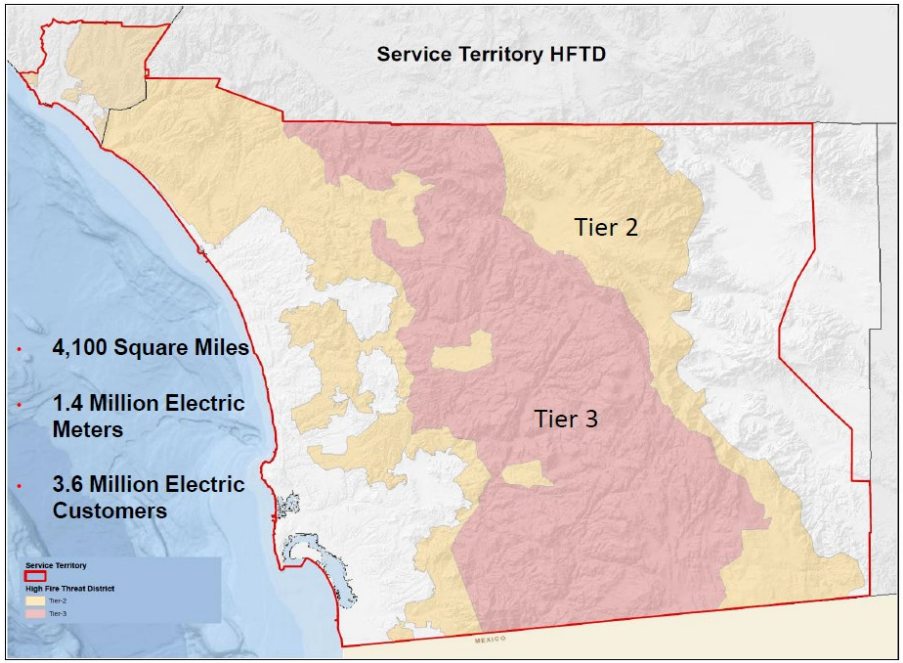


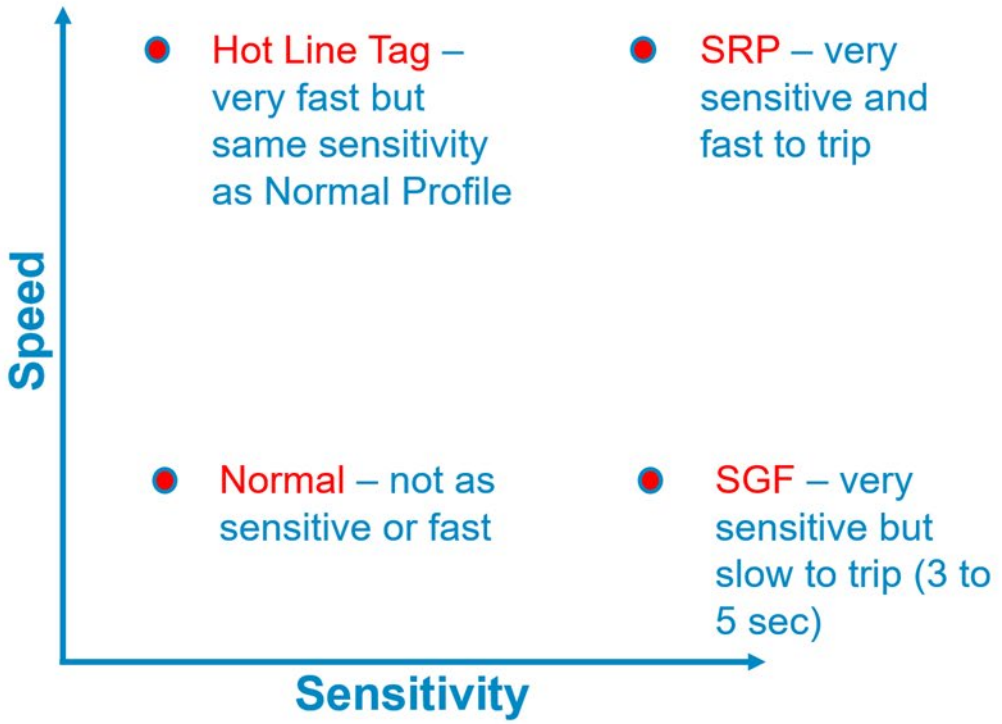
Figure 1: SDG&E Service Territory with HFTDs

When extreme fire weather conditions or PSPS events are forecasted, SDG&E remotely enables Sensitive Relay Profile (SRP) on its system; SRP includes settings which make protective devices such as reclosers and circuit breakers more sensitive to faults on the overhead distribution system and activate quickly to interrupt power. SDG&E pre-identifies and maintains a list of these devices and can quickly communicate with its distribution operations control center to enable SRP when conditions warrant and in observance of wildfire safety efforts.

SRP settings include standard settings for all HFTD circuits:

- The phase minimum to trip set is at 50% above peak load on the circuit spanning a 5-year history
- The ground minimum to trip is based on peak historical trends and set using a specific table contained within the settings methodology.
- Definite time set with 0.5 cycle delay

The advantage of these settings is that there is a definite tripping time for all fault currents above minimum to trip. The disadvantage is that devices potentially do not coordinate, so downstream faults may lock out multiple devices. If multiple devices trip during an event when sensitive settings are enabled, SDG&E retains protection engineers and field resources available 24/7 to review event records to help determine if mis-coordination contributed to the event. These standby resources review each event in real-time and provide detailed information back to our operations teams and the EOC for situational awareness.



Normal Profile – Typical setting used to coordinate isolation of only faulted segments (Enabled when not in RFW or Extreme FPI)

SGF – Sensitive Ground Fault protection to detect high impedance faults (Always enabled)

SRP – Sensitive Relay Profile settings on phase and ground set to trip very fast to reduce fault energy (Enabled during PSPS or Extreme FPI)

Hot Line Tag – Enabled for crew safety when performing hot work. Same setpoints as Normal Profile, but very fast to trip.

Reclosing – Blocked year-round in HFTD

Figure 2: SDG&E Sensitive Settings Comparison

Southern California Edison (SCE)

SCE operates an electric transmission/subtransmission/distribution system that serves approximately 15 million people through about 5 million customer accounts. SCE's service area spans about 50,000 square miles across central, coastal and Southern California, excluding the city of Los Angeles (served by LADWP) and other small cities served by municipal utilities. SCE's system includes about 900 distribution substations, 1.2 million distribution poles, 69,800 circuit miles of distribution primary lines, 31,000 circuit miles of distribution underground lines and 38,800 circuit miles of distribution overhead lines. The primary distribution voltage is predominantly 12 kV, with some large areas of 33kV, 16kV and 4 kV. Grounding configurations include both 3-wire uni-grounded and a 4-wire multi-grounded configuration. SCE mixes both 3-wire and 4-wire configurations on the same circuits.

Figure 2: SCE Service Territory

In 2018, SCE initiated a program to deploy fast curve settings at substation circuit breaker relays and automatic reclosers and developed a plan for upgrading non-compatible and older vintage electromechanical and microprocessor relays for feeder circuits in high fire risk areas between 2020-2024.

SCE expects to complete upgrades to over 90% of all circuit breaker relays in high fire risk areas by 2022, with the remaining circuits upgraded by 2024.

SCE uses multiples of normal minimum trip to set fast curve settings with a time delay of typically two cycles. Normal minimum trip for each device is set to 150% of peak load. These settings typically help coordinate with other line protection devices, including fuses. SCE is presently evaluating its fast curve settings to increase sensitivity while maintaining reliability and coordination with fuses.

PacifiCorp

PacifiCorp serves more than 780,000 customers in 243 communities across Oregon, Washington, and Northern California**.** In California, PacifiCorp provides electricity to approximately 45,000 customers via 63 substations, 2,520 circuit miles of distribution lines, and 800 circuit miles of transmission lines. The service territory spans nearly 11,000 square miles, with just under half in HFTDs. Approximately 1,200 miles (36%) of all overhead lines are located within the HFTDs, with about 850 miles of overhead distribution lines (260 circuits) and 350 miles of transmission lines in HFTDs. PacifiCorp's distribution system is comprised of both single and three-phase in a range of system voltages between 4.2 kV and 20.8 kV circuits in 3 wire delta, 3 wire uni-ground, 4 wire wye configurations.

Figure 3: PacifiCorp Service Territory

PacifiCorp conducted a pilot of Sophisticated Program Control Settings (SPCS) in 2021. This pilot evaluated the optimal approaches in using sensitive and sophisticated device settings to reduce wildfire risk and improve reliability. Devices, including relays, reclosers, and fuses, all have methods by which they are programmed to operate in response to a fault condition. If there is limited coordination between devices, it can increase the probability of equipment damage or delayed device operations, creating and extending an ignition risk. After experimenting and making minor modifications, PacifiCorp has adopted these settings as standard.

The settings profiles include (but are not limited to):

- Normal (fuse saving application): Instantaneous trip followed by reclosing attempts with time-overcurrent trips.
- Elevated risk, no line reclosers, fuses on the line: Substation breaker will have an instantaneous trip followed by single reclose attempt after sufficient time to limit the persistence of fire.
- Elevated risk, line reclosers: Substation breaker will have instantaneous trip with no reclose attempt.
- Extreme risk, no line reclosers, fuses on line: Substation breaker will have instantaneous trip with no reclose attempt.
- Safety hold: for line worker usage during line operations where no reclosing occurs.

These settings use definite time delays (12-cycles for substation breakers, 6-cycles between reclosers) to improve coordination. The settings also implement fuse overreach and harmonic blocking schemes. They are not currently enabling any sensitive ground fault detection.

Avista

Avista Utilities generates and transmits electricity and distributes natural gas to residential, commercial, and industrial customers. The service territory covers 30,000 square miles in eastern Washington, northern Idaho, and parts of southern and eastern Oregon. Avista provides electricity to 359,000 customers in two western states.

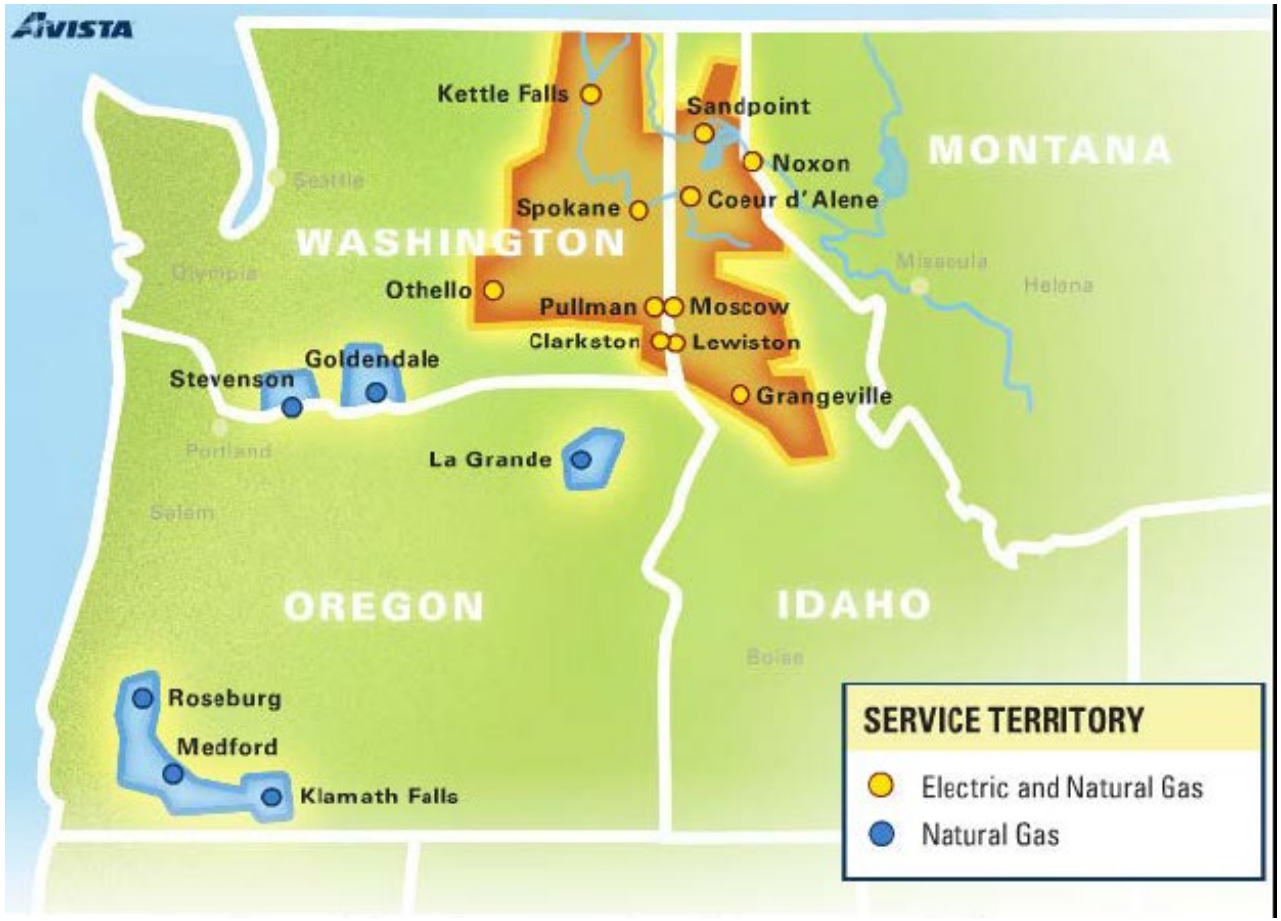


Figure 4: Avista Service Territory

Avista experiences a fire season beginning around mid-July and lasting until late September or early October. During this season, Avista has historically disabled instantaneous overcurrent (50) tripping and reclosing on its distribution protection system, seeking to reduce spark ignition potential while maintaining coordination via time-overcurrent (51) elements.

As part of its ongoing effort to strengthen its wildfire resiliency program, Avista devised a new approach to its distribution operations during the fire season that seeks to calculate circuit-specific fire risks and allow operators to alter relay operating behaviors in response to the fire risk dynamically. The feeder relays and reclosers are programmed with three different "Dry Land Modes". Each mode further reduces electrical fault energy by reprioritizing instantaneous overcurrent (50) elements over time-overcurrent (51) elements. In addition, reclosing is reduced or disabled.

The settings profiles include:

- Underreaching 50 elements – Reach stops short of downstream Dry Land Mode (DLM) Recloser and trips without any delay
- Overreaching 50 elements – Reaches to end of fused laterals in relays protection zone (and overreaches downstream DLM Recloser, so has a breaker-coordinated definite-time delay of 6 cycles
- 51 elements – Set for fuse coordination
- Per/phase 2nd Harmonic Inrush Blocking – Per/phase inrush blocking allows for fast tripping on faulted phase when reclosing into a fault (for Fire 2-Shot mode, see below)
- Base Dry Land Mode: Fast Trip on instantaneous overcurrent followed by a single reclose attempt and switching to time-overcurrent elements. This behavior will quickly clear temporary faults, reducing fire risk, but maintain service reliability by coordinating with fuses for permanent faults. Base DLM is used when there is lower fire risk on a circuit
- Fire 2-Shot: Fast Trip on instantaneous overcurrent followed by a single reclose attempt after and trip again on instantaneous overcurrent elements. Fire 2-Shot is used when there is elevated fire risk on a circuit
- Fire 1-Shot: Fast Trip on instantaneous overcurrent with no reclosing. Fire 1-Shot is used when there is high fire risk on a circuit

Avista calculates a fire risk potential considering various weather, environmental, and operational data for the different distribution circuits. Based on real-time fire risk calculations.

The protective devices on a specific circuit can be moved into the appropriate "Dry Land Mode", allowing for a dynamic scheme that attempts to balance fire resiliency with service reliability.

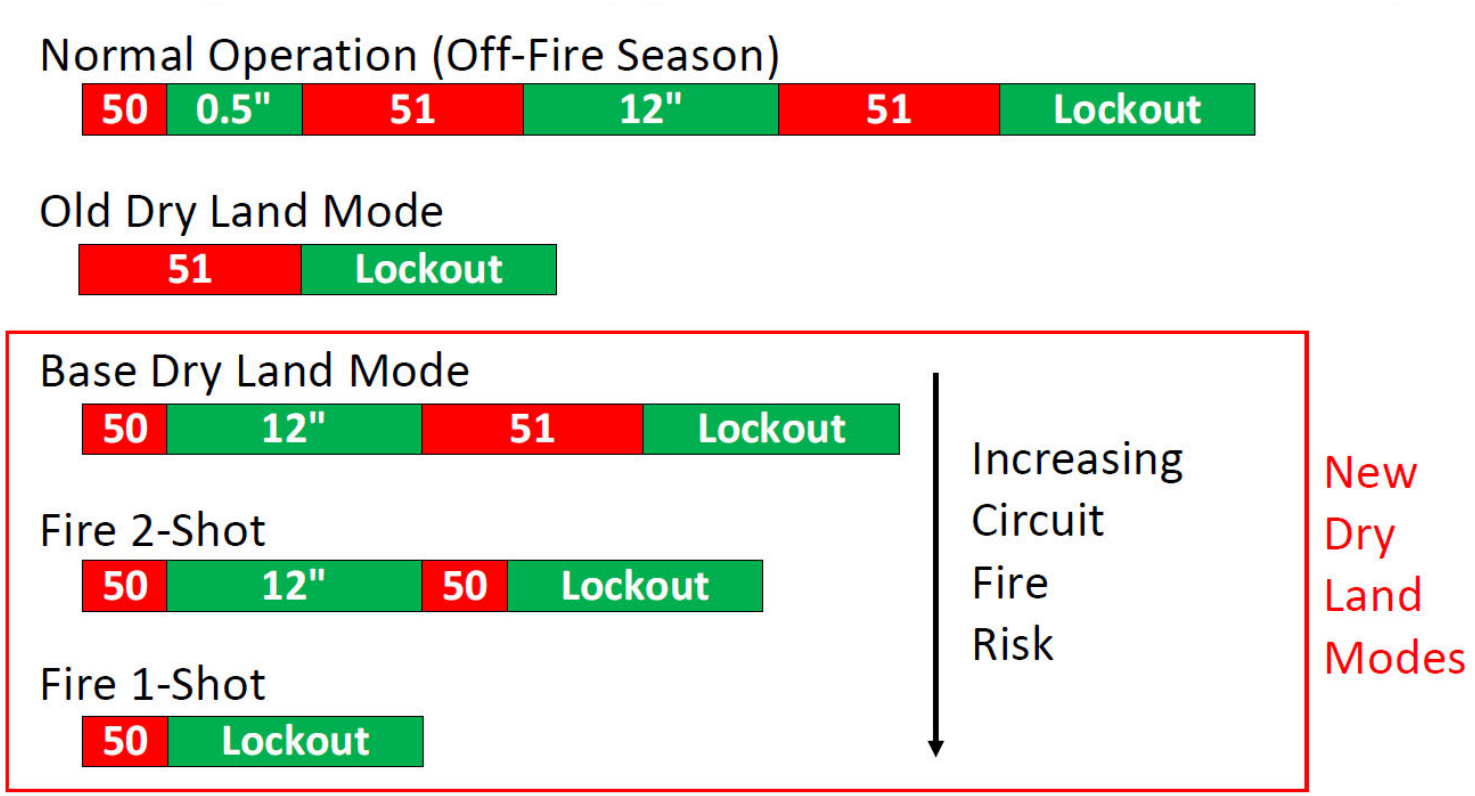


Figure 5: Avista's Fast Trip Approach (" indicates seconds)

Fire Risk Potential

- Risk = Probability · Impact

- Probability Factors
  - Wind Gusts
  - Sustained Winds
  - Wind Direction
  - Relative Humidity
  - Fuel Type
  - USDM Drought Index
  - Fire Preparedness Levels
  - Feeder OMS Data
  - Feeder Health

- Impact Factors
  - Public Safety
  - Societal Costs
  - WUI Map
    - Infrastructure
    - Development
    - Fuel Type
    - Ignition Probability
    - Fire-Spread Risk
    - WUI Tier 0-3

- Fire Risk Score for each distribution circuit
  - 8-Day Forecast

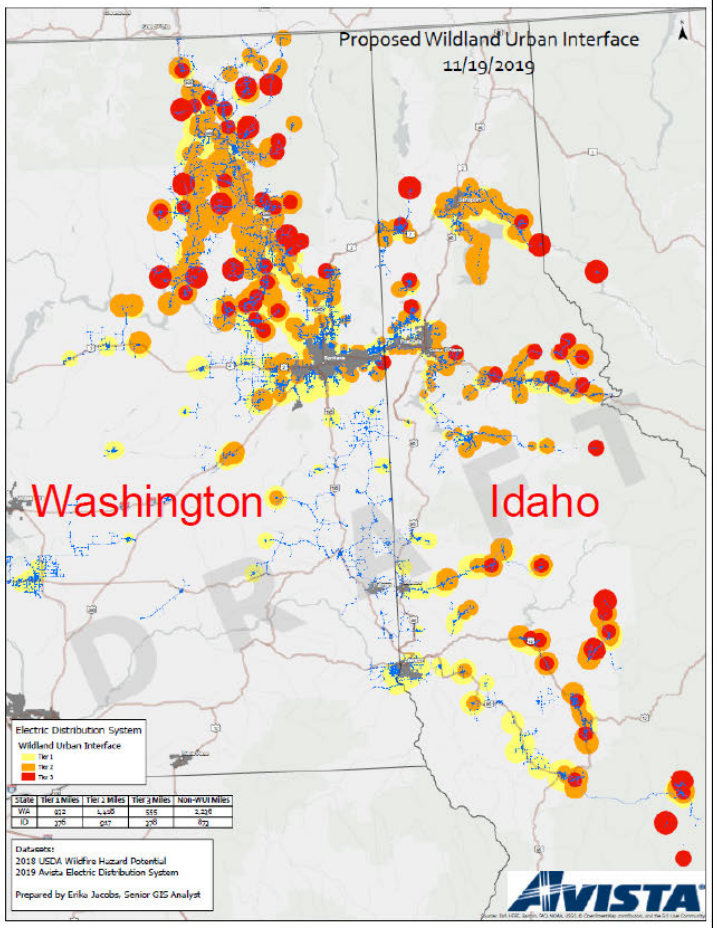


Figure 6: Avista's Fire Risk Potential Methodology

British Columbia Hydro (BC Hydro)

BC Hydro is a Crown corporation owned by the government and the people of British Columbia, Canada. They generate and deliver electricity to 95% of the population of BC. They serve over four million people. Electricity is delivered over 11,362 miles of transmission lines and 34,333 miles of distribution lines. The distribution system comprises 12.5 kV and 25 kV circuits and uses a 4-wire multi-ground configuration. Historically, BC Hydro experiences a fire season beginning around August and lasting until late September. However, the fire seasons have been starting earlier in recent years due to drier conditions.

Figure 7: BC Hydro Service Territory

BC Hydro performed lab testing and conducted a field pilot of distribution circuit fast trip settings. Their implementation used Siemens Fuse Saver (FS) devices. FS devices are capable of very fast tripping (1/2 cycle or 0.01s). However, these devices have limited load current ratings and fault duty capability (100A and 4kA, respectively), restricting their use to taps and lateral sections of circuits. The FS are programmed with coordinated tripping, fast tripping mode, and single-shot reclosing lockout settings. BC Hydro envisions using circuit specific settings that provide some level of coordination between devices. The Fast Trip settings were tested at Powertech before the field pilot. They do not implement any sensitive ground fault settings or high-impedance (HIF) fault detection schemes.

The fast trip settings are similar to hot line tag settings used for worker safety: 50ms Phase-overcurrent and 500 ms Ground-overcurrent. The settings are tailored to minimize false trips and provide better coordination.