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BEAR VALLEY ELECTRIC SERVICE

Enhanced Power Line Safety Settings Review

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ENHANCED POWER LINE SAFETY SETTING REVIEW

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"Issued For" Definitions:

- "Prelim" means this document is issued for preliminary review, not for implementation
- "Appvl" means this document is issued for review and approval, not for implementation
- "Impl" means this document is issued for implementation
- "Record" means this document is issued after project completion for project file

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1. EXECUTIVE SUMMARY

1.1 Introduction

Wildfires have been a growing concern across the United States and especially in the state of California. Electric utilities have been implementing fire mitigation strategies to combat growing wildfire exposure zones due to the potential of vegetation coming into contact with overhead lines and other infrastructure. Bear Valley Electric Service (BVES) has implemented a fast curve protection strategy to speed up fault clearing times to mitigate fire risk. This document is a review of BVES's present fast curve philosophy and contains recommendations to the philosophy which may provide more reliable fault clearing and provide greater circuit coverage under fire risk conditions. BVES's three (3) 34.5 kV circuits and seven (7) of BVES's 22, 4.16 kV circuits were analyzed using the present philosophy and reanalyzed using the revised philosophy to illustrate potential protection improvements. In addition to reviewing BVES's protection philosophy, a brief overview of other electric utility fire protection philosophies are provided for comparison.

1.2 Summary of Analysis

Fast Curve Protection Evaluation

BVES provided a Milsoft WindMil model of their service area that traverses high fire risk areas. Ten (10) circuits consisting of 18 programable protection devices (reclosers) were evaluated for wildfire and fast tripping protection. The protective device coverage of each fast curve setting was evaluated in regard to the percentage of the total conductor length of the zone where the fast curve setting will detect and clear faults. The study revealed 11 of the 18 protection devices considered in this study provide less than 90% coverage for their zone of protection with nine (9) of those devices providing less than 50% zone coverage. Evaluating existing settings for system normal conditions (with normal zones of protection that stops at fuses and Tripsavers) found circuits will experience protection coverage issues when using typical protection margins. Ground fault protection for 11 of the protection devices is not desirable, with some devices lacking ground overcurrent protection altogether. Solutions for this may require replacement of some oil reclosers that may not offer ground overcurrent protection.

Reducing the fast curve pickup setting of reclosers would be a means of increasing circuit coverage. To avoid undesired tripping of devices under load, a typical load security margin of 150% was used as a minimum protection threshold. This lower setting limit is estimated by looking at the peak load data from the previous 12 months at the head of the feeder.

Existing protection fast curve settings were evaluated for trip times for End-of-Line (EOL) faults, given an extended zone of protection that overtrips fuses and S&C Tripsavers. Ten (10) of the 18 protective devices were shown to trip slower than 12 cycles (0.2 seconds), with five (5) devices exceeding 30 cycles (0.5 seconds). Due to a combination of low fault current and higher pickup settings, five (5) devices will not trip for their EOL faults. The slowest operate time for an EOL phase fault is 56.94 cycles (0.95 seconds), and the slowest operate time for an EOL ground fault is 65.5 cycles (1.09 seconds). These are long trip times for fault clearing during high fire risk events, especially for instances where the fast curve protection will not be able to detect an EOL bolted fault.

Protection Philosophy Review

Modifications to the philosophy were investigated to increase circuit coverage and trip times of fast curve settings. Reducing the existing phase and ground fast curve pickup settings down to their minimum value while meeting load security margin criteria, will increase sensitivity of the settings, and provide greater circuit coverage. It may be possible to determine a phase minimum trip setting capable of riding through cold load pickup, but it is beyond the scope of this study.

BVES does not standardize on a particular curve type for its reclosers. Standardizing the fast curve setting to the TCC 101 curve will bring uniformity to the protection devices and will also greatly reduce the fault clearing times for EOL faults. Reducing the clearing time for faults greatly reduces the energy dissipated by the fault, reducing wildfire risks. Using proposed pickup settings and standardized fast curves will reduce the EOL clearing times below 12.0 cycles for those devices investigated. If BVES wishes to maintain separate slow protection, or more sensitive pickups with slow operation the wildfire fast protection can be programmed as a definite time element as discussed in Section 9. BVES has elected to use the definite time element on the 34.5kV devices to maintain time-overcurrent coordination upline with SCE protection. This will allow the definite time element to time concurrently with the normal time overcurrent elements, providing a more complex protection profile that will not lose normal protection sensitivity. The development of these settings do not account for device coordination with other protective devices. This protection is solely evaluated to provide sensitivity and fast tripping for wildfire prevention.

There is no industry standard providing guidelines on how to implement wildfire mitigation protection on distribution circuits. To provide some comparison of BVES's philosophy to other industry practice, the present fire mitigation methodology for two (2) utilities is discussed. These utilities operate service territory in the Southwest and Mountain west of the United States. Both entities utilize a fast curve to implement a fuse saving scheme in their everyday protection philosophy. During high fire days, reclosing is disabled, and the protection will only trip via the fast curve setting, significantly reducing tripping times. These settings generally have greater circuit coverage.

With a few modifications BVES can improve its fast curve tripping scheme to provide better circuit coverage and faster clearing times. This should provide adequate wildfire mitigation protection and aligns typical industry practices.

This study proposes an Enhanced Power Line Safety Setting (EPSS) philosophy that can be found in appendix A, and an EPSS Implementation Strategy that can be found in appendix B. Implementing the changes outlined in this report will increase protection reaches to 100% circuit coverage for nearly all circuits investigated and decrease EOL fault trip times to below 6.0 cycles.

2. BVES FAST CURVE PROTECTION REVIEW

BVES's fast curve protection philosophy has been extrapolated based on the provided existing setting files. The fast curve protection consists of disabling reclosing and slow curve trips, and tripping on the reclosers designated fast curve only. The fast curve setting is implemented in all programmable reclosers on the distribution lines. Recloser manufacturers and controllers vary throughout the system. S&C IntelliRupters and Cooper Form 6's are the most common protective device. The curve types vary per device, and no standardization to the curves or pickups appears to be made.

BVES is using current limiting fusing on all service transformers. BVES uses S&C Tripsavers across the distribution system, programmed to trip with slow fuse curves and provide reclosing. For the purposes of this study, these Tripsavers were treated the same as fuses. The intent for the recloser fast curve protection is to overtrip these devices to provide faster clearing times.

2.1 Protection Settings Guidelines

No protection setting guidelines were provided. Instead, existing setting files for the protection devices were analyzed to extrapolate a protection philosophy. There was no clear pattern to discern a settings philosophy. Device settings were compared to industry typical protection margins including IEEE Std. C37.230 – IEEE Guide for Protective Relay Applications to Distribution Lines. The following typical setting guidelines were used to evaluate BVES's time overcurrent elements protecting distribution circuits:

- Phase Sensitivity:
  - 1.5 times peak loading ≤ Minimum Phase Trip (Pickup) < $EOL_{LL}/2$ (50% reach margin)
- Ground Sensitivity:
  - 1.5 times peak load imbalance ≤ Minimum Ground Trip (Pickup) < $EOL_{SLG}/3$ (33% reach margin)
- Where EOL values are the minimum fault values in the relay's zone of protection, wildfire mitigation settings are required to be sensitive enough to see beyond Tripsavers and fused sections of the circuit.

Typical practice to account for fault impedance is to provide a reach margin by setting the pickup to some percentage below the smallest EOL bolted fault. While the short circuit model can provide estimated bolted fault currents, these values do not account for any fault impedance. It is difficult to predict a fault impedance as it depends on the nature of the fault, materials, environment, and many other factors. To ensure full coverage of a protection zone, the protection must trip for faults beyond Tripsavers and fused sections of the circuit. End-of-line faults are the minimum fault values seen by the recloser or protective device, including faults on overhead lines that are beyond fuses and Tripsavers. The zone of protection stops at other downline reclosers and transformers.

Since underground conductors are not susceptible to wildfire ignition, EOL faults beyond fuses and Tripsavers on underground line segments can be ignored. However, if the underground line is not protected by a fuse, Tripsaver, or other protective device then it's EOL faults must be included in the maximum trip thresholds.

Of the devices reviewed, six (6) do not implement ground overcurrent protection. Two (2) circuits do not implement ground protection. Two (2) of the devices without ground protection, are on circuits that have ground protection implemented elsewhere on that same circuit. Note: the peak load imbalance was not provided, so the ground minimum trip was estimated. The fast curve setting sensitivity is directly tied to the time overcurrent setting sensitivity. This relationship greatly affects the circuit coverage of the fast curve settings.

2.2 System Model and Assumptions

BVES provided the latest Milsoft WindMil distribution model for the study. The model required some updating to make it suitable for running short circuit analyses. A line loss study was conducted previously for BVES in June of 2021 which also used a BVES provided distribution model. The 2021 model was used to fill in any missing information in the latest provided WindMil model. For a list of updates and assumptions made on the 2021 model, please reference the 2021 Line Loss Report.

An updated equipment database (EQDB) was not provided with this latest model. The EQDB from the 2021 model was used. Additionally, the 34.5 kV circuit source impedance was not included in the latest model. The source impedance for the 34.5 kV Shay and Radford circuits were copied from the 2021 model. The 34.5 kV Baldwin source impedance was missing. Since both Baldwin and Shay are fed from SCE Goldhill, Baldwin was set to have the same source impedance as Shay. The 34.5kV OH lines existing construction “DefaultOHConst” was only rated to 4.16 kV. The 34.5 kV lines construction was updated to “DefaultOHConst34kV” or “DefaultUGConst34kV”.

The WindMil model provided does not contain correctly modeled consumer loads, so the voltage drop due to load conditions could not be accounted for while running the short circuit analyses. For all EOL fault current calculations, it was assumed 1.0 per unit voltage is supplied at each substation transformer 34.5 kV bus, and transformer DETCs are set at 100%, operating at nominal voltage. As there is no load in the model, substation feeder voltage regulators were ignored.

Distributed Energy Resources (DER) were not included in the provided WindMil model. Any fault infeed or reverse fault currents due to DER were not considered during short circuit analysis in this study.

There were multiple instances of missing conductor types. Where possible, these conductor types were copied over from the previous 2021 model. Instances where the conductor type could not be determined from the 2021 model were estimated based on surrounding conductor types of the same phasing on the circuit. The following table shows these issues and subsequent corrections.

TABLE 1: BVES WINDMIL MODEL CORRECTIONS

CIRCUIT NAME	ELEMENT NAME(S)	ASSUMED CONDUCTOR	NOTES
North Shore	UG104112, UG104113, UG104114, UG104115, UG104116	15KV 1000KCM AL EPR	Blank conductor size. Previous model shows this as OH line, while new model is UG. Updated to match UG primary conductor.
North Shore	UG_50940, UG_63213, UG_63214, UG_50904, UG_63212, UG_63211, UG_63210,	15KV #2 STR KCMIL AL	Unknown UG conductor. Updated to match other 1Ph UG conductor sizes on the circuit.
North Shore	UG_36757, UG_63223, UG_36732, UG_46353, UG_46290, UG_900134, UG_900135, UG_43392, UG_40691, UG_63371, UG_40705, UG_40722, UG_40398	15KV #2 STR KCMIL AL	Unknown UG conductor. Updated to match other 1Ph UG conductor sizes on the circuit.

TABLE 1: BVES WINDMIL MODEL CORRECTIONS			
CIRCUIT NAME	ELEMENT NAME(S)	ASSUMED CONDUCTOR	NOTES
Boulder	UG117955, UG117954, UG117953, UG117958, UG117957, UG117956, UG117949	15KV #2 STR KCMIL AL	Unknown UG conductor. Updated to match other 1Ph UG conductor sizes on the circuit.
North Shore	UG104112, UG104113, UG104114, UG104115, UG104116	15KV 1000KCM AL EPR	Blank conductor size. Previous model shows this as OH line, while new model is UG. Updated to match UG primary conductor.

2.3 Circuit Selection

Outage data for 2016-2024 was provided by BVES and was reviewed for all circuits. BVES requested the three (3) critical 34.5 kV lines (Baldwin, Radford, and Shay) be included in the study, since these lines feed the entire system. The remaining seven (7) circuits with the most unplanned outages were selected for study. Together, the ten (10) circuits reviewed for the study account for 59% of all unplanned outages between 2016-2024.

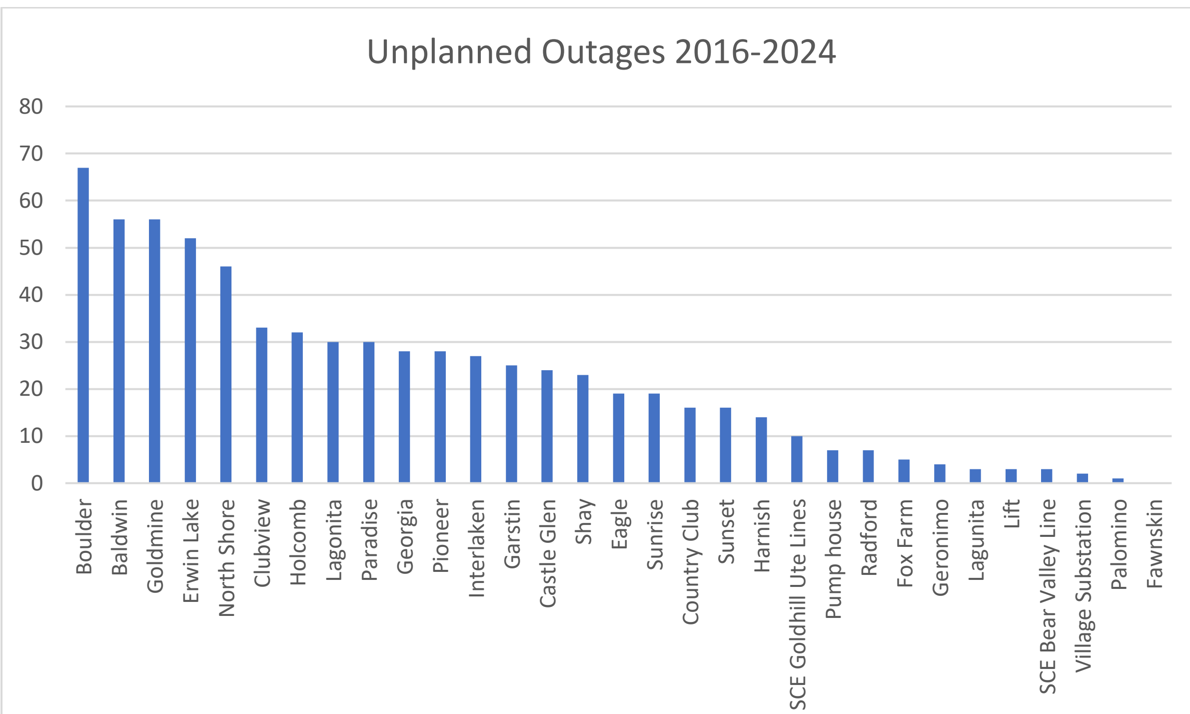

Figure 1: BVES Unplanned Outages 2016-2024

3. CIRCUIT TOPOGRAPHY

Since underground conductors are not a concern for wildfire mitigation, each protection zone was evaluated for their percentage of overhead conductors. The conductor milage shown is the sum of all conductor impedance lengths modeled within the zone of protection.

TABLE 2: TOPOGRAPHY OF CHOSEN CIRCUITS

SUBSTATION	CIRCUIT	DEVICE/ZONE OF PROTECTION	UG MILES IN ZONE/ PERCENT OF ZONE	OH MILES IN ZONE/ PERCENT OF ZONE
Baldwin	Baldwin	IR3430	1.02mi / 11%	8.24mi / 89%
Bear City	Holcomb	SUB	0.96mi / 7%	13.22mi / 93%
Fawnskin	North Shore	SUB	6.78mi / 67%	3.31mi / 33%
		AR805	1.03mi / 10%	9.16mi / 90%
		AR806	0.49mi / 13%	3.28mi / 87%
Maltby	Erwin Lake	SUB	6.24mi / 26%	17.90mi / 74%
		AR1128	1.26mi / 24%	3.92mi / 76%
Moonridge	Clubview	SUB	0.31mi / 6%	4.99mi / 94%
		AR424	0.05mi / 1%	5.18mi / 99%
	Goldmine	SUB	1.08mi / 12%	8.04mi / 88%
		AR405	4.18mi / 45%	5.16mi / 55%
Radford	Radford	IR3470	0.02mi / 1%	2.82mi / 99%
Shay	Shay	IR3440	0.72mi / 4%	17.33mi / 96%
Village	Boulder	SUB	0.52mi / 35%	0.97mi / 65%
		AR102	0.54mi / 8%	6.58mi / 92%
		AR105	0.87mi / 8%	9.92mi / 92%
	Lagonita	SUB	1.01mi / 47%	1.12mi / 53%
		AR145	0.41mi / 7%	5.71mi / 93%

The Fawnskin Substation North Shore feeder recloser has a significant amount of underground conductors with approximately 67% of its 10.09 miles zone of protection being underground. The next largest mix is the Village Substation Lagonita feeder recloser with 2.13 miles of conductor within this zone, 47% are underground and 53% are overhead. The Moonridge Substation Goldmine feeder line recloser AR405 has approximately 9.34 miles of conductor within its zone, with 45% underground and 55% overhead. The remaining protection zones are primarily overhead construction. Although the BVES 34.5 kV lines (Baldwin, Radford, and Shay) are primarily overhead conductor, BVES will be converting this conductor to covered conductor within the next year. While still subject to downed conductors, the covered wire will greatly mitigate concerns for vegetation to come into contact with lines.

4. CIRCUIT ANALYSIS

The ten (10) selected circuits were analyzed using the available WindMil model and existing device setting files. The fast curve settings for each of the devices (settings are shown in Appendix C) were evaluated for the overall coverage in their zone of protection. The zone of protection was defined to be all areas downline of the recloser (including downline of fuses and Tripsavers) but would not reach past downline breakers, distribution transformers, or other circuit reclosers. The fast curve setting is not intended to coordinate with fuses.

The reach margins below show the protection pickup setting as a percentage of the minimum phase or ground fault seen within that devices zone of protection. To provide typical sensitivity, the phase pickup should be less than 50% of the minimum phase fault, and the ground pickup should be less than 33% of the minimum ground fault. Devices highlighted in red are over 100%, meaning the pickup setting for these devices will not see bolted faults at the end of its zone of protection. These faults may not clear or may depend on a slower tripping device, such as a fuse, to clear the fault. Devices highlighted in orange, are below the minimum bolted fault current but above the 50% phase and 33% ground reach margins. These devices may see a bolted fault at the end of its zone of protection, however a high impedance fault may not be cleared by these devices.

TABLE 3: PHASE AND GROUND REACH MARGINS OF SELECTED FEEDERS/DEVICES

SUBSTATION	CIRCUIT	DEVICE/ ZONE OF PROTECTION	PHASE PICKUP (A)	GROUND PICKUP (A)	PROTECTION REACH MARGIN	
					PHASE	GROUND
Baldwin	Baldwin	IR3430	580	100	42%	n/a*
Bear City	Holcomb	SUB	560	280	61%	43%
Fawnskin	North Shore	SUB	570	340	40%	36%
		AR805	380	230	134%	91%
		AR806**	200	n/a	101%	109%**
Maltby	Erwin Lake	SUB	580	300	112%	71%
		AR1128**	200	n/a	48%	59%**
Moonridge	Clubview	SUB**	560	n/a	51%	84%**
		AR424**	560	n/a	85%	144%**
	Goldmine	SUB**	560	n/a	47%	80%**
		AR405**	560	n/a	49%	109%**
Radford	Radford	IR3470	170	10	6%	n/a*
Shay	Shay	IR3440	580	100	27%	n/a*
Village	Boulder	SUB	640	320	37%	19%
		AR102	580	260	49%	67%
		AR105	380	230	62%	69%
	Lagonita	SUB	640	370	31%	17%
		AR145	640	370	84%	55%

*Baldwin, Radford and Shay 34.5 kV circuit are delta connected and do not have ground faults
**Device does not have a ground protection element set. The phase overcurrent element pickup was used to calculate reach margins for phase-to-ground faults.

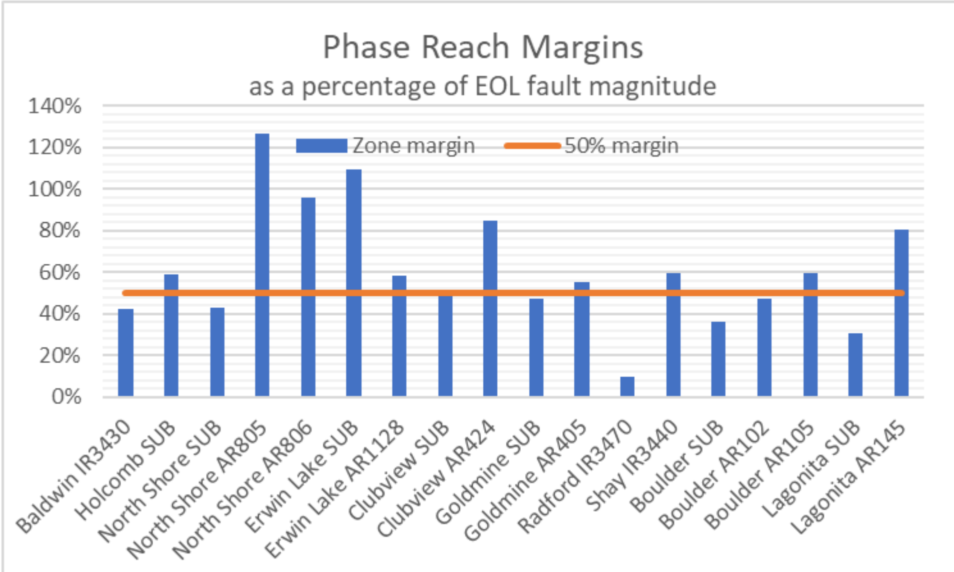

Figure 2: Studied Circuit's Phase Reach Margins

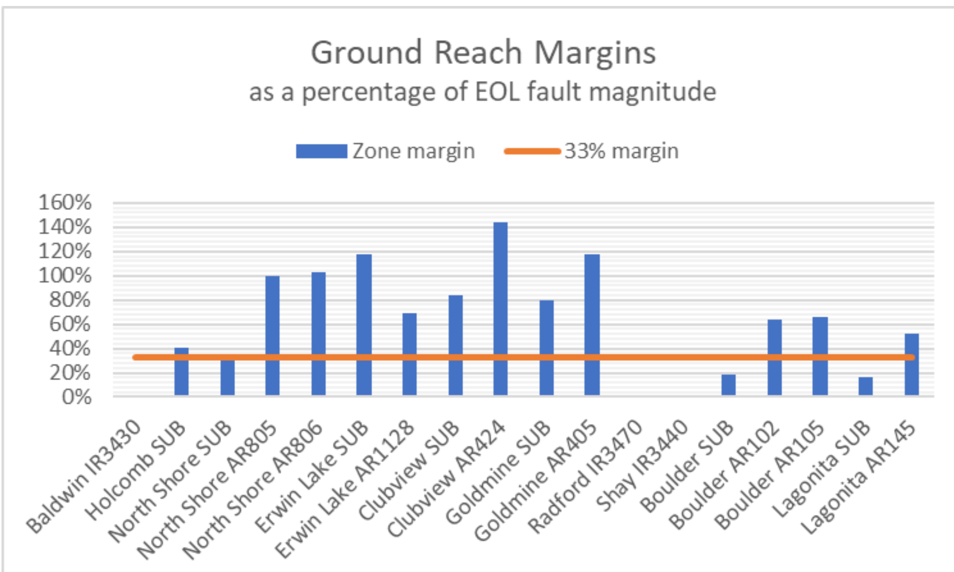

Figure 3: Studied Circuit's Ground Reach Margins

Of the devices reviewed, eight (8) do not meet typical phase protection margins, and 13 out of the 15 devices (excluding 34.5 kV delta circuits) do not meet typical ground protection margins. Three (3) of the devices will not pick up for an EOL phase fault and three (3) will not pick up for an EOL phase-to-ground fault.

4.1 Circuit Coverage - Without Reach Margins

The below table details the effective protection for devices that do not cover their entire zone of protection when no reach margin (0%) is applied. It tabulates how many conductor miles within the zone of protection have bolted fault magnitudes that are below the pickup setting. Note, that in this case the zone of protection is defined as overtripping fuses and Tripsavers but stops at transformers and series reclosers. It also shows how many of those conductor miles are overhead line construction, which are more susceptible to wildfire concerns.

TABLE 4: CIRCUIT COVERAGE WITHOUT REACH MARGINS

SUBSTATION	CIRCUIT	DEVICE	PHASE FAULT ZONE UNPROTECTED		GROUND FAULT ZONE UNPROTECTED	
			TOTAL MI / % ZONE	OH MI / % ZONE	TOTAL MI / % ZONE	OH MI / % ZONE
Baldwin	Baldwin	IR3430*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Bear City	Holcomb	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Fawnskin	North Shore	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR805	0.86 / 8.45%	0.86 / 8.45%	0 / 0%	0 / 0%
		AR806**	0.10 / 2.6%	0.10 / 2.6%	0.74 / 19.59%	0.74 / 19.59%
Maltby	Erwin Lake	SUB	0.23 / 0.97%	0.23 / 0.97%	0 / 0%	0 / 0%
		AR1128**	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Moonridge	Clubview	SUB**	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR424**	0 / 0%	0 / 0%	1.74 / 33.21%	1.69 / 32.27%
	Goldmine	SUB**	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR405**	0 / 0%	0 / 0%	0.49 / 5.2%	0.18 / 1.93%
Radford	Radford	IR3470*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Shay	Shay	IR3440*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Village	Boulder	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR102	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR105	0 / 0%	0 / 0%	0 / 0%	0 / 0%
	Lagonita	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR145	0 / 0%	0 / 0%	0 / 0%	0 / 0%

*Baldwin, Radford and Shay 34.5 kV circuit are delta connected and do not have ground faults
**Device does not have a ground protection element set. The phase overcurrent element pickup was used to calculate reach margins for phase-to-ground faults.

The Clubview Feeder line recloser AR424 is of greatest concern, as nearly one-third of the circuit is unprotected from ground faults. AR424 is a McGraw/Edison RX Oil recloser. Protection of its zone could be achieved by replacing this device with an electronic recloser that utilizes ground overcurrent protection. Additionally, the substation feeder protection is an IntelliRupter. This device has the capability of programming ground overcurrent settings; however, it is currently not enabled. The ground protection could be enabled in this device and set to overreach the downline oil recloser until AR424 can be replaced. North Shore AR805 and AR806 also have reach concerns. These circuits have 0.75 miles or more of unprotected conductor. The other circuits have smaller unprotected sections and may present less risk. These protection gaps may be fixable with a settings adjustment to make the pickups more sensitive. These adjustments are discussed further in the recommendations section of this report.

4.2 Circuit Coverage - With Reach Margins

The below table details the effective protection for devices when using typical protection margins (50% EOL for phase, 33% EOL for ground). It tabulates how many conductor miles within the zone of protection have bolted fault magnitudes that are below the pickup setting with the protection margins. Note, that in this case the Zone of protection is defined as overtripping fuses and Tripsavers but stops at transformers and series reclosers.

TABLE 5: CIRCUIT COVERAGE WITH REACH MARGINS

SUBSTATION	CIRCUIT	DEVICE	PHASE FAULT ZONE UNPROTECTED		GROUND FAULT ZONE UNPROTECTED	
			TOTAL MI / % ZONE	OH MI / % ZONE	TOTAL MI / % ZONE	OH MI / % ZONE
Baldwin	Baldwin	IR3430*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Bear City	Holcomb	SUB	0.35 / 2.46%	0.34 / 2.42%	1.09 / 7.69%	1.09 / 7.69%
Fawnskin	North Shore	SUB	0 / 0%	0 / 0%	0.11 / 1.05%	0.11 / 1.05%
		AR805	3.03 / 29.76%	3.02 / 29.59%	8.21 / 80.48%	7.97 / 78.18%
		AR806**	2.4 / 63.52%	2.36 / 62.44%	3.78 / 100%	3.28 / 86.94%
Maltby	Erwin Lake	SUB	4.33 / 17.93%	3.81 / 15.79%	15 / 62.15%	12.31 / 51.03%
		AR1128**	0 / 0%	0 / 0%	4.18 / 80.63%	3.81 / 73.55%
Moonridge	Clubview	SUB**	0.04 / 0.67%	0.04 / 0.67%	3.36 / 63.34%	3.18 / 59.97%
		AR424**	1.63 / 31.24%	1.63 / 31.24%	5.23 / 100%	5.18 / 99.06%
	Goldmine	SUB**	0 / 0%	0 / 0%	5.7 / 62.48%	5.7 / 62.48%
		AR405**	0 / 0%	0 / 0%	8.03 / 86.01%	4.26 / 45.63%
Radford	Radford	IR3470*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Shay	Shay	IR3440*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Village	Boulder	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR102	0 / 0%	0 / 0%	1.67 / 23.39%	1.38 / 19.45%
		AR105	0.94 / 8.71%	0.93 / 8.62%	7.24 / 67.07%	6.73 / 62.37%
	Lagonita	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR145	4.76 / 77.63%	4.43 / 72.3%	4.31 / 70.29%	3.98 / 64.96%

*Baldwin, Radford and Shay 34.5 kV circuit are delta connected and do not have ground faults
**Device does not have a ground protection element set. The phase overcurrent element pickup was used to calculate reach margins for phase-to-ground faults.

Out of the 18 protection devices, 13 zones meet, or nearly meet (10% of the zone or less) the phase reach margin. Three (3) devices have the majority of the zone meeting phase reach margins (50% of the zone or less), and two (2) devices have the majority of the zone that does not meet phase reach margins (greater than 50% of the zone).

For ground protection, four (4) zones meet, or nearly meet (10% of the zone or less) the ground reach margin. Two (2) devices have the majority of the zone meeting ground reach margins (50% of the zone or less), and nine (9) devices have the majority of the zone that does not meet ground reach margins (greater than 50% of the zone).

4.3 Circuit Coverage - Normal Zones of Protection - With Reach Margins

Before implementing a separate wildfire protection strategy to increase sensitivity, protection was checked for its coverage for normal conditions. This evaluation is to see if the reach issues are existing, or if reach issues are only caused when adding the extra sensitivity for wildfire mitigation. In this case the protection zones do not overtrip fuses and Tripsavers. The below table details the effective protection for devices when using typical reach margins (50% EOL for phase, 33% EOL for ground).

TABLE 6: CIRCUIT COVERAGE, NORMAL ZONES OF PROTECTION WITH REACH MARGINS

SUBSTATION	CIRCUIT	DEVICE	PHASE FAULT ZONE UNPROTECTED		GROUND FAULT ZONE UNPROTECTED	
			TOTAL MI / % ZONE	OH MI / % ZONE	TOTAL MI / % ZONE	OH MI / % ZONE
Baldwin	Baldwin	IR3430*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Bear City	Holcomb	SUB	0.34 / 10.91%	0.34 / 10.91%	0.12 / 3.68%	0.12 / 3.68%
Fawnskin	North Shore	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR805	0.84 / 43.6%	0.84 / 43.6%	0.96 / 49.98%	0.96 / 49.98%
		AR806**	0 / 0%	0 / 0%	0.23 / 100%	0.23 / 100%
Maltby	Erwin Lake	SUB	2.84 / 44.4%	2.84 / 44.4%	2.74 / 42.75%	2.74 / 42.75%
		AR1128**	0 / 0%	0 / 0%	0.52 / 82.49%	0.52 / 82.49%
Moonridge	Clubview	SUB**	0.04 / 1.19%	0.04 / 1.19%	2.09 / 69.89%	2.09 / 69.89%
		AR424**	1.44 / 84.89%	1.44 / 84.89%	1.7 / 100%	1.7 / 100%
	Goldmine	SUB**	0 / 0%	0 / 0%	0.63 / 22.77%	0.63 / 22.77%
		AR405**	0 / 0%	0 / 0%	1.34 / 69.57%	1.34 / 69.57%
Radford	Radford	IR3470*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Shay	Shay	IR3440*	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Village	Boulder	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR102	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR105	0.62 / 28.12%	0.62 / 28.12%	0.85 / 38.65%	0.85 / 38.65%

TABLE 6: CIRCUIT COVERAGE, NORMAL ZONES OF PROTECTION WITH REACH MARGINS						
SUBSTATION	CIRCUIT	DEVICE	PHASE FAULT ZONE UNPROTECTED		GROUND FAULT ZONE UNPROTECTED	
			TOTAL MI / % ZONE	OH MI / % ZONE	TOTAL MI / % ZONE	OH MI / % ZONE
	Lagonita	SUB	0 / 0%	0 / 0%	0 / 0%	0 / 0%
		AR145	1.13 / 55.47%	1.13 / 55.47%	0.96 / 47.02%	0.96 / 47.02%

*Baldwin, Radford and Shay 34.5 kV circuit are delta connected and do not have ground faults
**Device does not have a ground protection element set. The phase overcurrent element pickup was used to calculate reach margins for phase-to-ground faults.

When evaluating the protective devices based on normal protection zones, 11 of the devices do not cover their entire zones given typical reach margins. Zone protection issues for six (6) of these devices could be resolved by adding ground protection. While including a separate protection philosophy could improve sensitivity for wildfire protection, it would be more beneficial to adjust the existing protection settings to be more sensitive to provide better coverage, even in normal conditions.

5. CIRCUIT LOAD MARGIN ANALYSIS

To increase sensitivity to detect faults at the end of a zone of protection, the pickup/trip can be decreased; however, the pickup should not be decreased such that it may cause undesirable trips during normal operation with heavily loaded conditions. A typical load security margin of 150% peak load was used for the phase evaluation. Note, this margin does not necessarily cover cold load scenarios. Typically ground minimum pickups are set above the circuit peak load imbalance. As no load imbalance data was provided, it was assumed a circuit max imbalance would be no more than 30%. Peak load values were provided from the previous 12 months for each feeder head. Since there was no load data for the line reclosers, these margins were calculated off the station load as a conservative estimate. The load security margins for the line reclosers will likely be larger if the recloser has less load than the station.

Devices highlighted in green have acceptable load security margins, and the pickup settings may be decreased to improve protection sensitivity.

TABLE 7: PHASE AND GROUND LOAD SECURITY MARGINS OF SELECTED FEEDERS/DEVICES						
SUBSTATION	CIRCUIT	DEVICE/ZONE OF PROTECTION	PHASE PICKUP (A)	GROUND PICKUP (A)	LOAD SECURITY MARGIN	
					PHASE	GROUND
Baldwin	Baldwin	IR3430	580	100	158%	27%
Bear City	Holcomb	SUB	560	280	208%	104%
Fawnskin	North Shore	SUB	570	340	201%	120%
		AR805	380	230	134%	81%
		AR806*	200	n/a	70%	n/a*
Maltby	Erwin Lake	SUB	580	300	118%	61%

TABLE 7: PHASE AND GROUND LOAD SECURITY MARGINS OF SELECTED FEEDERS/DEVICES						
SUBSTATION	CIRCUIT	DEVICE/ZONE OF PROTECTION	PHASE PICKUP (A)	GROUND PICKUP (A)	LOAD SECURITY MARGIN	
					PHASE	GROUND
		AR1128*	200	n/a	41%	n/a*
Moonridge	Clubview	SUB*	560	n/a	185%	n/a*
		AR424*	560	n/a	185%	n/a*
	Goldmine	SUB*	560	n/a	113%	n/a*
		AR405*	560	n/a	113%	n/a*
Radford	Radford	IR3470	170	10	103%	6%
Shay	Shay	IR3440	580	100	117%	20%
Village	Boulder	SUB	640	320	139%	70%
		AR102	580	260	126%	57%
		AR105	380	230	83%	50%
	Lagonita	SUB	640	370	124%	72%
		AR145	640	370	124%	72%
*Device does not have a ground protection element set. Load security margins cannot be calculated for these devices.						

Adjusting pickups lower, for tighter load security margins may be enough to increase protection sensitivity in some cases. The Moonridge Substation Clubview circuit has protection coverage issues, however there is plenty of load security margin available to increase sensitivity in these devices. The Maltby Substation Erwin Lake feeder recloser also has protection coverage issues, however the load security margin for the phase is less than the desired 150%, so other protection coverage solutions may be required. The ground load security margins may be able to be decreased, however these are only estimates as there was no load imbalance data available. The historical load imbalance should be analyzed for adequate margins before lowering the ground pickup.

6. FAULT CLEARING TIME ANALYSIS

During high fire danger it is desirable to clear faults as fast as possible to limit the fault energy and prevent possible fire ignition. The operate times of the fast curves were evaluate for EOL faults within the device's zone of protection. The zone of protection is defined as overtripping fuses and Tripsavers but stops at transformers and series reclosers. Note, these operate times are for bolted fault magnitudes. The fast curves are not definite time. Due to the inverse-time nature of the fast curves higher impedance faults may result in lower fault magnitudes and thus longer trip times. Highlighted clearing times are those that exceed the desired limit of 12.0 cycles (0.2 seconds).

TABLE 8: EXISTING PROTECTION DEVICE SETTINGS EOL FAULTS CLEARING TIME						
			PHASE PROTECTION		GROUND PROTECTION	
SUBSTATION	CIRCUIT	DEVICE	EOL FAULT (A)	EOL CLEARING TIME (CYC)	EOL FAULT (A)	EOL CLEARING TIME (CYC)
Baldwin	Baldwin	IR3430*	1374.4	9.16	n/a*	n/a*
Bear City	Holcomb	SUB	910.8	56.94	651.4	10.74
Fawnskin	North Shore	SUB	1442.3	3.29	952.1	4.70
		AR805	283.8	Does Not Clear	252.9	17.00
		AR806**	197.9	Does Not Clear	184.5	Does Not Clear
Maltby	Erwin Lake	SUB	518.6	Does Not Clear	424.0	30.15
		AR1128**	414.4	3.90	338.8	4.42
Moonridge	Clubview	SUB**	1105.7	16.59	666.6	65.50
		AR424**	655.2	6.60	389.8	Does Not Clear
	Goldmine	SUB**	1185.6	15.34	699.2	49.41
		AR405**	1136.7	4.11	516.0	Does Not Clear
Radford	Radford	IR3470*	2727.4	9.43	n/a*	n/a*
Shay	Shay	IR3440*	2127.3	6.94	n/a*	n/a*
Village	Boulder	SUB	1720.2	2.97	1708.9	2.92
		AR102	1183.5	3.92	386.6	30.52
		AR105	610.4	4.64	332.1	7.22
	Lagonita	SUB	2043.3	5.53	2190.2	2.80
		AR145	758.6	25.47	674.2	17.41

*Baldwin, Radford and Shay 34.5 kV circuit are delta connected and do not have ground faults
**Device does not have a ground protection element set. The phase overcurrent element was used to calculate trip times for phase-to-ground faults.

From the results in the table, ten (10) of the 18 devices exceed a desired 12.0 cycle clearing time, including five (5) devices that do not trip for the EOL faults at all. The slowest fast curve clearing time for phase faults is 56.94 cycles. The slowest fast curve clearing time for ground faults is 65.5 cycles. While these meet the typical clearing times for regular time overcurrent settings, 15-65.5 cycles can be excessive to clear a fault during high fire risk events. These clearing times are longer than some other California utilities fast curve clearing times, as seen in Section 7.3.

7. OTHER JURISDICTIONS FIRE MITIGATION PHILOSOPHY

To provide context to BVES's wildfire mitigation strategies, the existing philosophy was compared in light to other utility's practices as many utilities are implementing fire mitigation strategies in California and across the United States. The philosophies range from more stringent tree trimming policies, installing current limiting fuses, converting to covered overhead conductor, converting to underground construction, or switching to a more sensitive/faster protection scheme. The following are protection schemes implemented by two utilities aimed at preventing wildfires.

7.1 Utility A

This utility's service territory includes southwest United States. Their fire season tends to run 8-10 months of the year.

- Normal Operation Philosophy and Criteria:
    - Phase Time Overcurrent:
        - Pickup set at 1.5-2.0 times load at device
        - Set less than 1/3 of lowest available phase fault current at end of protective zone
        - Fuse saving on phase and ground elements
    - Ground Time Overcurrent:
        - Pickup set less than 1/3 of lowest available maximum ground fault current at end of protective zone
    - Phase/Ground IT:
        - Set with 3.0 cycle delay
- Fire Season (Fast/Sensitized) Operation Philosophy and Criteria:
    - Phase/Ground Time Overcurrent:
        - Pickups set approximately 75% of normal pickup
        - Reclosing is disabled
        - Downstream fuse coordination is sacrificed when this setting in active.
        - Same protection curves are utilized between fire season and normal operation.
    - Phase/Ground IT:
        - Pickup set same as Normal Operations
        - Lockout enabled
    - High impedance fault detection always on. Utility has custom SEL logic for tripping using the Hi-Z tripping quantities.

When the fire mitigation settings group is active the time overcurrent sensitivity is increased by 25%. The reclosing is disabled, and the relay will trip and lockout on one fast curve shot. The fast curve is not standardized across all relays. The curve settings typically used are U4 (extremely inverse) or a 163 recloser curve. The curve type may vary from setting to setting depending on what will work best for coordination on the feeder.

The use of the IT setting can give very fast clearing for portions of the protective zone but is unlikely to give 100% coverage. Fire mitigation was not the goal of implementing the IT setting. Increasing the sensitivity of the time overcurrent elements will increase the protective reach of the setting and will consequently decrease relay operating times. How much affect increasing sensitivity has on relay operating times greatly depends on the curve type and available fault current. The increased sensitivity will always have a positive effect on reducing relay operating times.

7.2 Utility B

This utility's service territory includes parts of the mountain west

- Normal Operation Philosophy and Criteria:
    - Phase Time Overcurrent:
        - Pickup set at one-half lowest phase-to-phase end-of-line fault
        - Set at 100-140% of line conductor rating
        - Set at 100% of connected kVA
        - Fuse saving scheme is implemented with one fast shot on phase and ground elements.
    - Ground Time Overcurrent:
        - Pickup set less than 1/3 of lowest available maximum ground fault current at end-of-line fault
        - Set at 100% highest single-phase connected kVA
        - Set at 33% of phase pickup
- Patrol Philosophy and Criteria:
    - Slow setting only with 1 shot to lockout. Enabled if a patrol has been conducted and nothing has been found
- Red Flag (Fire Mitigation):
    - Reclosing disabled
    - Slow curves disabled
    - 6.0 cycle time adder incorporated to coordinate with downstream reclosers.
    - Downstream fuse coordination is sacrificed when this setting in active.
    - Desired future implementation to include the high impedance detection logic
    - Replacing all expulsion type fuses with current limiting type fuses

When the fire mitigation setting is active the relay will trip and lockout on the fast curve setting. All relays have a fast curve utilizing the 101 recloser curve on phase and ground overcurrent elements. The 101 recloser curve will trip in approximately 1.0 cycle at 5.0 times the pickup value. The slowest the curve will detect a fault and trip is around 6.0 cycles. Included with the 6.0 cycle time adder the recloser will trip for phase and ground faults in approximately 10.0 cycles accounting for the recloser clearing time.

The protection sensitivity requirements dictate that the relays zone of protection must extend past downstream fuses. This methodology leads to the fast curve being set sensitive enough to detect and clear faults on all sections of line downstream. When the fire mitigation setting is active all phase and ground faults should be detected and cleared in 10.0 cycles or less.

7.3 Other California Utility Fast Trip Times

The below list is a summary of fast curve settings and fast curve trip times of other California utilities. These are provided by the PG&E study "Utility Benchmarking of Fast Trip Schemes and Relay Technologies for Fire Mitigation". These operate times can be compared with BVES fast curve trip times.

- PG&E: instantaneous trip with definite time delay not to exceed 0.1 sec (6.0 cycles)
- SCE: fast curve trip with time delay of 2.0 cycles

- SDG&E: instantaneous trip with delay of 0.5 cycles
- PacifiCorp: instantaneous trip with delay of 12.0 cycles for station breaker, 6.0 cycles of reclosers

The fast operate times of these selected utilities vary from 0.0-12.0 cycles.

8. RECOMMENDATIONS

8.1 Ground Element Incorporation

Six (6) out of the eighteen (18) protection devices do not utilize a ground protection element. Clubview Feeder AR424, Goldmine Feeder AR405, and North Shore Feeder AR806 are oil reclosers and may only offer phase protection. The Moonridge Substation Clubview and Goldmine Feeder reclosers, Erwin Lake AR1128, are IntelliRupters. IntelliRupters offer both phase and ground overcurrent protection. Not utilizing the ground element causes the phase element to be relied upon for quickly clearing phase-to-ground faults. From the analysis on the existing settings this leads to minimal ground fault coverage.

TABLE 9: GROUND REACH MARGINS OF DEVICES WITH NO GROUND PROTECTION

SUBSTATION	CIRCUIT	DEVICE/ ZONE OF PROTECTION	RECLOSER TYPE/ CONTROLLER	PH PU (A)	GND PU (A)	PROTECTION REACH MARGIN
						GROUND
Fawnskin	North Shore	AR806*	McGraw/Edison 6H	200	n/a	109%*
Maltby	Erwin Lake	AR1128*	IntelliRupter	200	n/a	59%*
Moonridge	Clubview	SUB*	IntelliRupter	560	n/a	84%*
		AR424*	RX	560	n/a	144%*
	Goldmine	SUB*	IntelliRupter	560	n/a	80%*
		AR405*	McGraw/Edison R	560	n/a	109%*

*Device does not have a ground protection element set. The phase overcurrent element pickup was used to calculate reach margins for phase-to-ground faults.

Ground elements operate on zero sequence current, which is less susceptible to tripping for high loads assuming that the loads are balanced across phases. The ground element can be set much more sensitively to detect high-impedance line-to-ground faults. It is recommended to replace all oil reclosers with three-phase electronically controlled reclosers that offer ground overcurrent protection. For the existing IntelliRupters, which already offer ground overcurrent protection, it is recommended to enable this element and enable ground elements on all the 4.16 kV distribution circuits.

8.2 Pickup Reduction

To identify which device pickups can be reduced, the below table compares each zone's reach margin to its load security margin. This shows which zones require more sensitivity and whether there is enough load security margin to reduce the pickups.

TABLE 10: EXISTING SUBSTATION LOAD SECURITY MARGINS VS PROTECTION REACH MARGINS

SUBSTATION	CIRCUIT	DEVICE / ZONE	PH PU (A)	GND PU (A)	LOAD SECURITY MARGIN		PROTECTION REACH MARGIN	
					PHASE	GROUND	PHASE	GROUND
Baldwin	Baldwin	IR3430	580	100	158%	27%	42%	n/a*
Bear City	Holcomb	SUB	560	280	208%	104%	61%	43%
Fawnskin	North Shore	SUB	570	340	201%	120%	40%	36%
Maltby	Erwin Lake	SUB	580	300	118%	61%	112%	71%
Moonridge	Clubview	SUB**	560	n/a	185%	n/a**	51%	84%
	Goldmine	SUB**	560	n/a	113%	n/a**	47%	80%
Radford	Radford	IR3470	170	10	103%	6%	6%	n/a*
Shay	Shay	IR3440	580	100	117%	20%	27%	n/a*
Village	Boulder	SUB	640	320	139%	70%	37%	19%
	Lagonita	SUB	640	370	124%	72%	31%	17%

*Baldwin, Radford and Shay 34.5 kV circuit are delta connected and do not have ground faults.
**Device does not have a ground protection element set. The phase overcurrent element was used to calculate ground reach margins.

Minimum phase and ground pick up values were calculated for these circuits while still satisfying the load security margins (>150% phase, and >30% ground). These pickup values are the lowest the circuit load will allow to offer the greatest protection sensitivity and fastest trip times. Circuit device coordination was not considered as typically the fast curves are not coordinated downline and fuse coordination is usually sacrificed for faster trip times during wildfire mitigation operations. The below table shows the protection reach margins for the calculated minimum pickups.

TABLE 11: SUBSTATION PROTECTION REACH MARGINS WITH CALCULATED MINIMUM PICKUPS

SUBSTATION	CIRCUIT	DEVICE / ZONE	PH PU (A)	GND PU (A)	PROTECTION REACH MARGIN	
					PHASE	GROUND
Baldwin	Baldwin	IR3430	551	111	40%	n/a*
Bear City	Holcomb	SUB	404	81	44%	12%
Fawnskin	North Shore	SUB	426	86	30%	9%
Maltby	Erwin Lake	SUB	738	148	142%	35%
Moonridge	Clubview	SUB	456	92	41%	14%
	Goldmine	SUB	744	149	63%	21%
Radford	Radford	IR3470	248	50	9%	n/a*
Shay	Shay	IR3440	747	150	35%	n/a*
Village	Boulder	SUB	691	139	40%	8%
	Lagonita	SUB	772	155	38%	7%

*Baldwin, Radford and Shay 34.5 kV circuits are delta connected and do not have ground faults.
All load security margins while at minimum trip values will be 150% for the phase and 30% for the ground.

Some substation feeders did not have issues with phase coverages, and setting the pickup to the load security margin actually raised the pickup. These pickup values can be left at the existing lower value if desired, as that will only increase sensitivity and improve fault clearing times. However, there may be concerns for tripping under peak load conditions. These values should be evaluated to ensure adequate security for peak loads. Also, the protection device's continuous current ratings should be considered when raising pickups to ensure the new values do not exceed equipment ratings. IntelliRupter's are rated for 630 A (800 A optional) and Cooper VWE are rated for 560 A (800 A optional).

Changing the pickups to the load security margin threshold provides adequate protection reach margins for all substation protection devices except for Maltby Substation Erwin Lake feeder recloser (4.82 miles of conductor or 20% of the zone is outside phase reach margins, 0.88 miles of conductor or 3.66% of the zone is unprotected), and Moonridge Substation Goldmine feeder recloser (0.24 miles of conductor or 2.63% of the zone outside of phase reach margins).

If instead the Erwin Lake and Goldmine feeder recloser pickups were set to the very maximum value that still satisfies the protection reach margins (<50% EOL phase, <33% EOL ground), the load security margins would look as follows:

TABLE 12: SUBSTATION LOAD SECURITY MARGINS WITH PICKUPS SET AT PROTECTION REACH MARGINS

SUBSTATION	CIRCUIT	DEVICE / ZONE	PH PU (A)	GND PU (A)	LOAD SECURITY MARGIN		PROTECTION REACH MARGIN	
					PHASE	GROUND	PHASE	GROUND
Maltby	Erwin Lake	SUB	259	141	53%	29%	50%	33%
Moonridge	Goldmine	SUB	592	233	119%	47%	50%	33%

The Goldmine feeder recloser can meet protection margins and still be set above peak load with a reduced load margin of 119%. Erwin Lake feeder recloser is not able to meet protection margins and still be set above peak load. Peak single-phase load seen by the Erwin Lake Feeder recloser is 491.4 A, and the minimum EOL phase fault is only 518.6 A. This makes it difficult to differentiate an EOL phase fault from load current. This may be alleviated by installing another series recloser downline from the Erwin Lake substation. This would shorten the zone of protection bringing the EOL fault location closer to the substation. Ideally, the new recloser would also see a smaller peak load current, allowing it to have a more sensitive pickup that would be able to protect for the 518.6 A EOL phase fault. TripSavers can be programmed with fast curves, including S&C 101 curves. TripSavers could be re-programmed to provide fast tripping protection for line sections outside of the protection reach margins, as a temporary solution.

Another option would be to enable a negative sequence element on the Erwin Feeder recloser; however, this would only be sensitive to line-to-line faults and would not detect three-phase balanced faults. The phase zone margin may still be limited by the minimum EOL three-phase fault of 659 A. This would allow the pickup to be increased to 329 A, which would only increase the load security margin to 67%. Additionally, the Erwin Lake feeder recloser is a Cooper VWE. It may be necessary to confirm the controller used is capable of negative sequence overcurrent tripping. It is assumed the controller is a Cooper Form 6, which has negative sequence overcurrent available.

Table 11 shows, in most cases, setting the fast curve pickup to the minimum load security margins will yield adequate sensitivity to cover the zones of protection for EOL phase and ground faults. If historical load data can be provided at the line recloser locations those devices can be evaluated for adjusting the pickups lower where necessary.

Note, that adjusting the pickups does not account for device coordination. Typically for wildfire mitigation efforts, the fast curves are not coordinated downline, and fuse coordination is usually sacrificed in favor of faster trip times. Some of the evaluated pickups are high and may impact upline coordination with the substation transformer protection. They may also be set above conductor emergency load ratings. These evaluated pickup values are intended for fast curve wildfire mitigation use and did not consider other circuit protection criteria. It is recommended to still employ separate slow curve protection to cover those protection concerns or conduct a thorough coordination and protection study before implementing these pickups for device normal protection.

8.3 Negative Sequence Protection Elements

The data from the ten (10) circuits in Table 11 showed that the majority of phase protection concerns can be addressed by setting the pickup settings to the minimum load security margin thresholds. The majority of protection will not require negative sequence overcurrent protection. Negative sequence protection can be used in unique scenarios, such as the Erwin Lake Feeder recloser, where the minimum EOL phase-to-phase fault is near the peak load current.

The negative sequence element provides added sensitivity for phase-to-phase faults and will also be able to detect ground faults. The phase domain to sequence domain relationship for phase-to-phase faults is:

$$I_{\emptyset} = \sqrt{3} * I_2$$

Where,

- $I_{\emptyset}$ is the phase current measured by the relay
- I_2 is the calculated negative sequence current

The negative sequence element will be $\sqrt{3}$ more sensitive than a standard phase overcurrent relay setting. Another benefit of the negative sequence element is it is set based on circuit imbalance rather than peak loading. Load is mostly a balanced condition at the substation feeder head, consisting of small magnitudes of negative sequence currents. Although the load can become more imbalanced further out on the distribution line, the imbalance will usually be a fraction (assumed to be 30% or less in this report) of the phase load current. This allows negative sequence overcurrent elements to be set more sensitively than the normal phase overcurrent elements. The ground elements are already set to be above potential imbalances on the circuit so the negative sequence element can match the ground setting.

The negative sequence element cannot replace the phase overcurrent element but can be added to the existing elements to gain better phase-to-phase fault coverage. For three-phase faults, the negative sequence current is near zero and would not provide adequate protection for these faults.

8.4 Fast Curve Standardization

The below table shows existing phase protection and fault clearing times from slowest to fastest.

TABLE 13: EXISTING FAST PHASE PROTECTION SETTINGS AND EOL FAULT CLEAR TIMES							
SUBSTATION	CIRCUIT	DEVICE / ZONE	PU	CURVE	TD	TIME ADDER	EOL FAULT CLEAR TIME (CYC)
Fawnskin	North Shore	AR805	380	S&C 101	1	0	Does Not Clear
Fawnskin	North Shore	AR806	200	A	1	0	Does Not Clear
Maltby	Erwin Lake	SUB	580	101	1	0	Does Not Clear
Bear City	Holcomb	SUB	560	S&C 102	1	0	56.94
Village	Lagonita	AR145	640	104	1	0	25.47
Moonridge	Clubview	SUB	560	SEL U5	1	0	16.59
Moonridge	Goldmine	SUB	560	SEL U5	1	0	15.34
Radford	Radford	IR3470	170	SEL U3	1	0	9.43
Baldwin	Baldwin	IR3430	580	SEL U5	0.6	0	9.16
Shay	Shay	IR3440	580	SEL U5	0.6	0	6.94
Moonridge	Clubview	AR424	560	A	1	0	6.60
Village	Lagonita	SUB	640	104	1	0	5.53
Village	Boulder	AR105	380	S&C 101	1	0	4.64
Moonridge	Goldmine	AR405	560	A	1	0	4.11
Village	Boulder	AR102	580	S&C 101	1	0	3.92
Maltby	Erwin Lake	AR1128	200	S&C 101	1	0	3.90
Fawnskin	North Shore	SUB	570	102	1	0	3.29
Village	Boulder	SUB	640	101	1	0	2.97

The fast phase curves do not appear to be standardized across devices. Some of the slowest trip times use the SEL US curves. Five (5) out of the seven (7) slowest devices use the SEL U3 and U5 curves.

TABLE 14: EXISTING FAST GROUND PROTECTION SETTINGS AND EOL FAULT CLEAR TIMES							
SUBSTATION	CIRCUIT	DEVICE / ZONE	PU	CURVE	TD	TIME ADDER	EOL FAULT CLEAR TIME (CYC)
Fawnskin	North Shore	AR806*	200*	A*	1*	0*	Does Not Clear
Moonridge	Clubview	AR424*	560*	A*	1*	0*	Does Not Clear
Moonridge	Goldmine	AR405*	560*	A*	1*	0*	Does Not Clear
Moonridge	Clubview	SUB*	560*	SEL U5*	1*	0*	65.50
Moonridge	Goldmine	SUB*	560*	SEL U5*	1*	0*	49.41
Village	Boulder	AR102	260	S&C 106	1	0	30.52

TABLE 14: EXISTING FAST GROUND PROTECTION SETTINGS AND EOL FAULT CLEAR TIMES							
SUBSTATION	CIRCUIT	DEVICE / ZONE	PU	CURVE	TD	TIME ADDER	EOL FAULT CLEAR TIME (CYC)
Maltby	Erwin Lake	SUB	300	106	1	0	30.15
Village	Lagonita	AR145	370	106	1	0	17.41
Fawnskin	North Shore	AR805	230	S&C 102	1	0	17.00
Bear City	Holcomb	SUB	280	S&C 106	1	0	10.74
Village	Boulder	AR105	230	S&C 102	1	0	7.22
Fawnskin	North Shore	SUB	340	106	1	0	4.70
Maltby	Erwin Lake	AR1128*	200*	S&C 101*	1*	0*	4.42
Village	Boulder	SUB	320	106	1	0	2.92
Village	Lagonita	SUB	370	106	1	0	2.80
*Device does not have a ground protection element set. The phase overcurrent element protection was used to calculate trip times.							

The fast ground curves do not appear to be standardized across devices. Two (2) out of the six (6) slowest devices use the SEL U5 curves based on phase settings. Three (3) out of the six (6) slowest devices use 106 curves. The two fastest devices also use the 106 curve; however Boulder and Lagonita feeder reclosers have fast operate times because the EOL ground faults for these zones are much larger (1709 A and 2190 A respectively) than their pickups.

The SEL US curves have a strong inverse property, when high impedance fault currents are low and approach the minimum trip threshold, the clearing time rapidly increases. These curves are typically used for coordination purposes because their profile matches well to coordinate with fuse curves. Additionally, their inverse characteristic gives longer trip times at low currents to provide better ride-through capability for temporary system disturbances while still providing fast trip times for high fault currents. However, this curve choice does not fit well with wildfire mitigation purposes which require sensitivity and fast clearing times for high impedance faults.

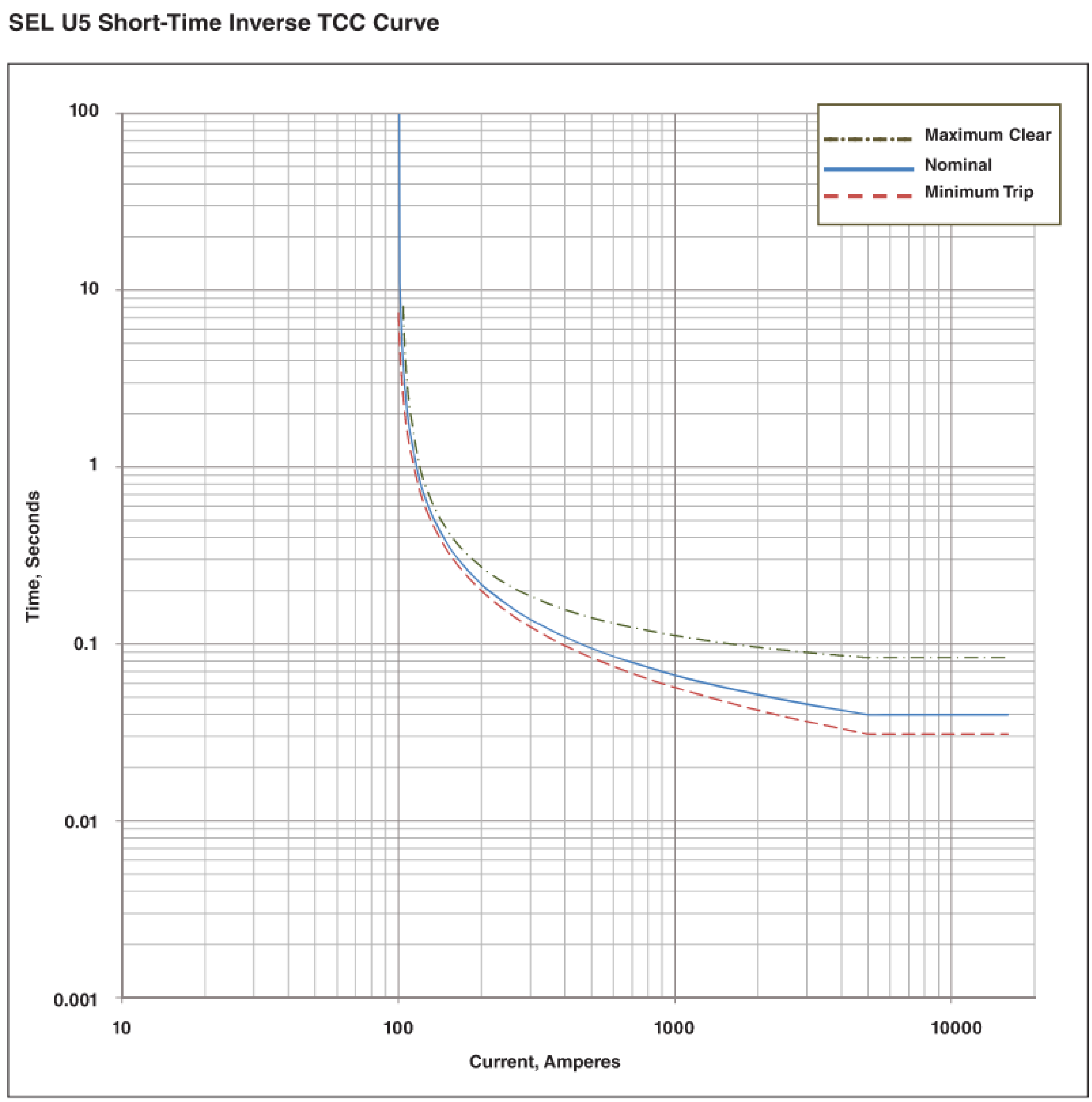

Figure 4: SEL-U5 Time Current Curve Characteristic for S&C IntelliRupters

The S&C 106 curve has a more linear inverse property. While it may not have as long of trip times as the SEL U-5 curve near the minimum trip threshold, trip times can still approach 1.0 second.

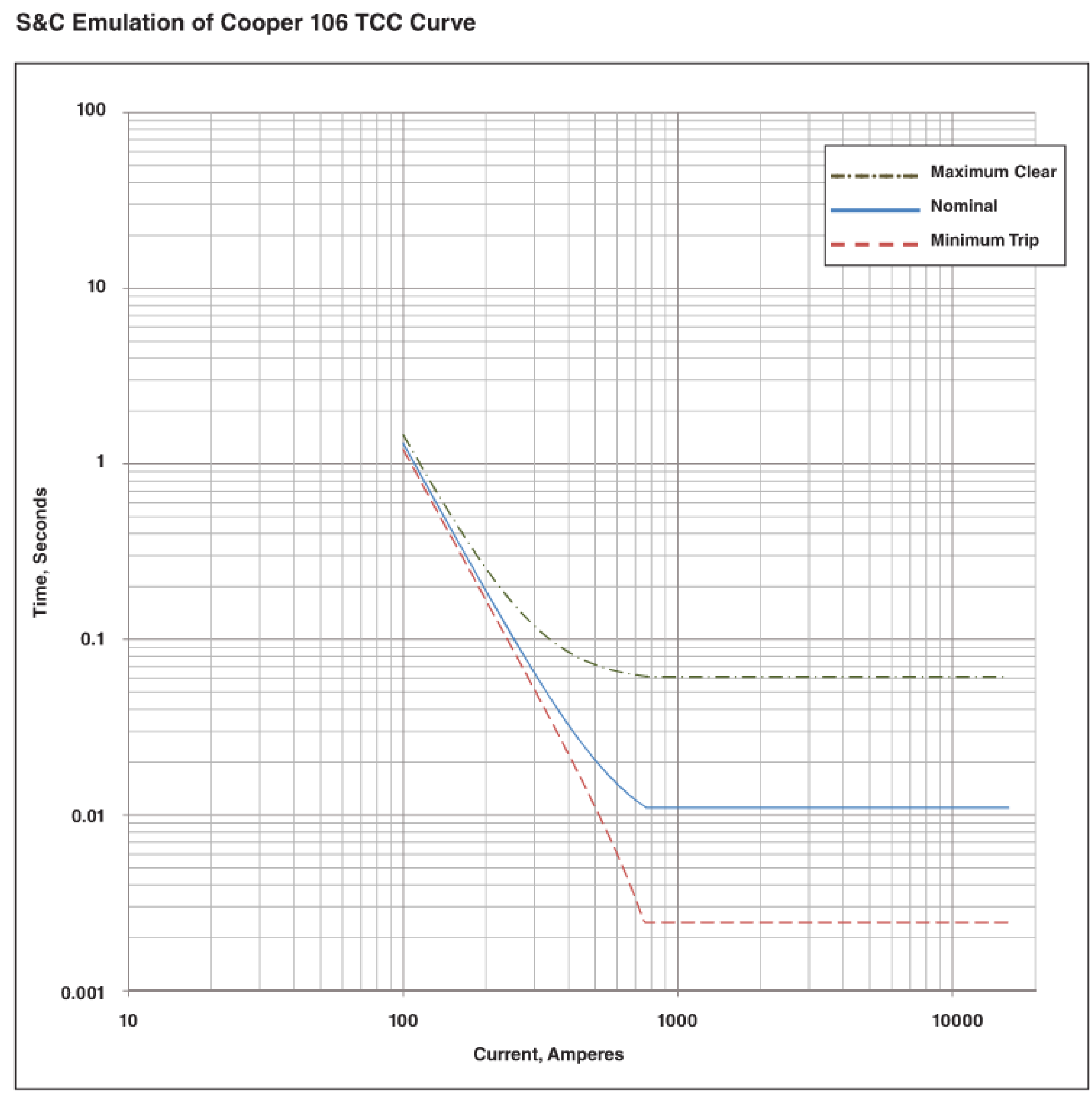

Figure 5: Cooper 106 Time Current Curve Characteristic for S&C IntelliRupters

Conversely, six (6) out of the eight (8) fastest clearing phase devices use the 101 or "A" type curve. This curve was designed as a fast trip curve and has a much flatter profile. High impedance faults that approach the minimum trip setting will trip only slightly slower.

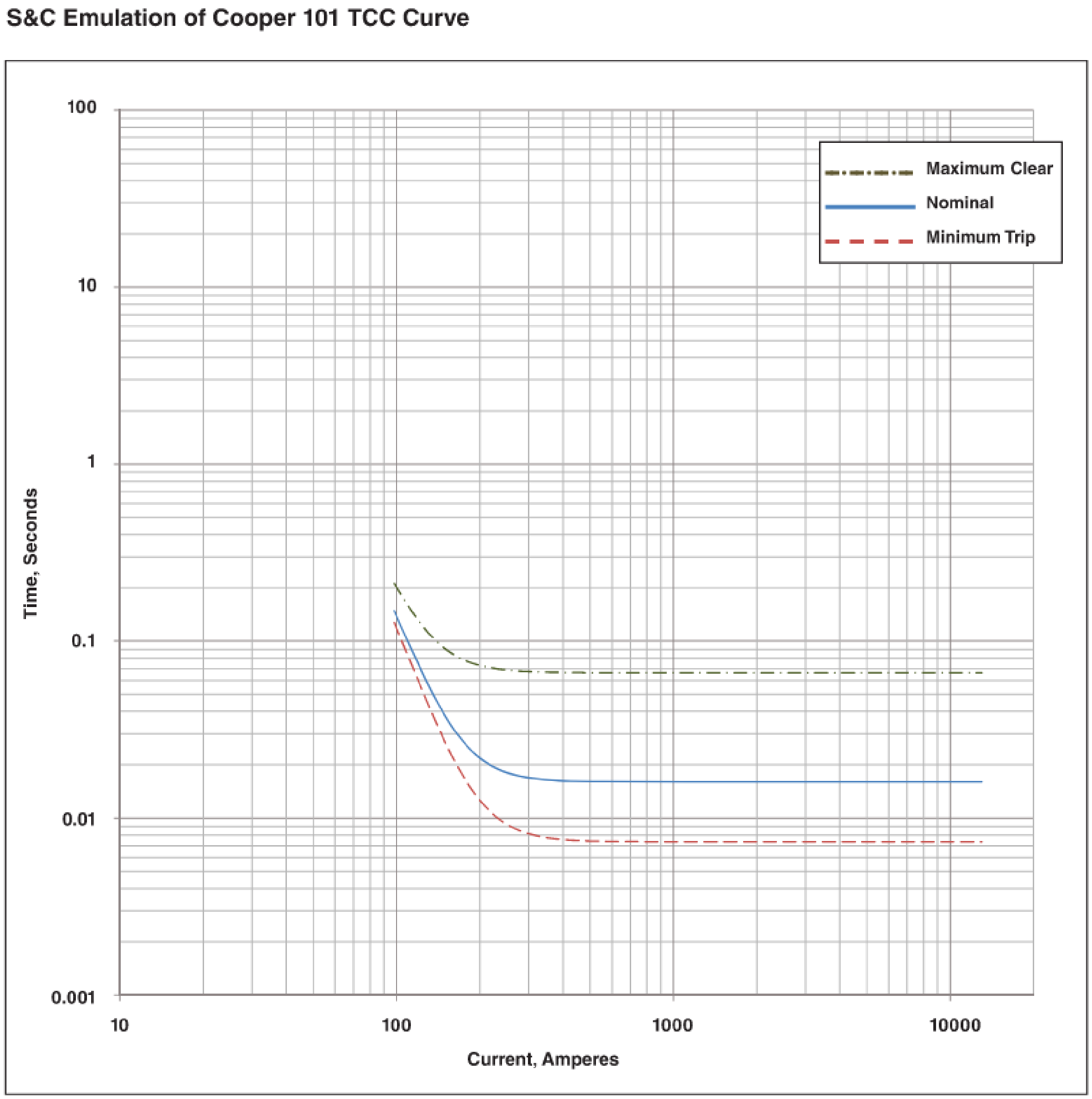

Figure 6: Cooper 101 Time Current Curve Characteristic for S&C IntelliRupters

Using the TCC 101 (A) curve is commonly used in the existing settings and is fast enough for wildfire mitigation in most cases. The slowest maximum clear time for IntelliRupter TCC 101 curves, at the pickup threshold, 12.0 cycles (0.2 seconds). Any fault currents greater than this threshold will clear faster than 12.0 cycles. Note, this curve is recloser dependent. Cooper Form 6 controllers and R series oil reclosers will be about the same or faster than the IntelliRupter curve. This is not the case for H-Type oil reclosers like North Shore AR806. H-Type recloser A curve maximum clearing time is 36.0 cycles (0.6 seconds).

8.5 Re-evaluated Fast Curve Settings

Phase fast curves were changed to reflect new calculated pickup values, curve types and time dials as detailed in the preceding sections. Substation zones of protection were reduced to the minimum pickup that still satisfies the load security margins and line reclosers pickup was set to the very maximum value that still satisfies the protection reach margins. All phase and ground curves were set to TCC 101 (A). Oil circuit reclosers have been replaced with IntelliRupters. The following tables shows proposed revised settings.

Note, these settings do not account for device coordination with other protective devices. This protection is theoretical and is solely evaluated to provide sensitivity and fast tripping for wildfire prevention. Due to concerns with coordinating the 34.5kV protection devices upline against SCE protection, BVES has elected to employ a separate Definite Time element for fast curve tripping in these devices, such that the existing Time-overcurrent element and coordination will be maintained.

TABLE 15: RE-EVALUATED PHASE FAST CURVE PROTECTION SETTINGS

SUBSTATION	CIRCUIT	DEVICE / ZONE	MIN PU	CURVE	TIME DIAL	TIME ADDER
Baldwin	Baldwin	IR3430	551	DT*	1	6 cy
Bear City	Holcomb	SUB	404	S&C 101	1	0
Fawnskin	North Shore	SUB	426	101	1	0
		AR805	141	S&C 101	1	0
		AR806	98	S&C 101	1	0
Maltby	Erwin Lake	SUB	738	101	1	0
		AR1128	207	S&C 101	1	0
Moonridge	Clubview	SUB	456	S&C 101	1	0
		AR424	327	S&C 101	1	0
	Goldmine	SUB	744	S&C 101	1	0
		AR405	568	S&C 101	1	0
Radford	Radford	IR3470	248	DT*	1	6 cy
Shay	Shay	IR3440	747	DT*	1	6 cy
Village	Boulder	SUB	691	101	1	0
		AR102	591	S&C 101	1	0
		AR105	305	S&C 101	1	0
	Lagonita	SUB	772	101	1	0
		AR145	379	101	1	0

*Definite Time (DT) curves are being applied to 34.5kV devices to maintain coordination with SCE.

TABLE 16: RE-EVALUATED GROUND FAST CURVE PROTECTION SETTINGS						
SUBSTATION	CIRCUIT	DEVICE / ZONE	MIN PU	CURVE	TIME DIAL	TIME ADDER
Baldwin	Baldwin	IR3430	111	DT***	1	6 cy
Bear City	Holcomb	SUB	81	S&C 101	1	0
Fawnskin	North Shore	SUB	86	101	1	0
		AR805	84	S&C 101	1	0
		AR806*	61	S&C 101	1	0
Maltby Maltby	Erwin Lake	SUB	148	101	1	0
		AR1128**	112	S&C 101	1	0
Moonridge	Clubview	SUB**	92	S&C 101	1	0
		AR424*	129	S&C 101	1	0
	Goldmine	SUB**	149	S&C 101	1	0
		AR405*	171	S&C 101	1	0
Radford	Radford	IR3470	50	DT***	1	6 cy
Shay	Shay	IR3440	150	DT***	1	6 cy
Village	Boulder	SUB	139	101	1	0
		AR102	128	S&C 101	1	0
		AR105	110	S&C 101	1	0
	Lagonita	SUB	155	101	1	0
		AR145	224	101	1	0

*These devices are existing oil reclosers that may not offer ground protection. It is assumed in this case that the oil reclosers will be replaced with S&C IntelliRupters to allow fast tripping ground overcurrent protection.
**Device does not currently have a ground protection element set. The ground overcurrent element is assumed to be enabled for these settings.
***Definite Time (DT) curves are being applied to 34.5kV devices to maintain coordination with SCE.

The table below shows the EOL fault clearing times for the re-evaluated protection settings.

TABLE 17: RE-EVALUATED PROTECTION SETTINGS EOL FAULTS CLEARING TIME						
SUBSTATION	CIRCUIT	DEVICE	PHASE PROTECTION		GROUND PROTECTION	
			EOL FAULT (A)	EOL CLEARING TIME (CYC)	EOL FAULT (A)	EOL CLEARING TIME (CYC)
Baldwin	Baldwin	IR3430*	1374.4	6.00	n/a*	n/a*
Bear City	Holcomb	SUB	910.8	3.79	651.4	3.56
Fawnskin	North Shore	SUB	1442.3	2.99	952.1	2.96

TABLE 17: RE-EVALUATED PROTECTION SETTINGS EOL FAULTS CLEARING TIME						
SUBSTATION	CIRCUIT	DEVICE	PHASE PROTECTION		GROUND PROTECTION	
			EOL FAULT (A)	EOL CLEARING TIME (CYC)	EOL FAULT (A)	EOL CLEARING TIME (CYC)
		AR805	283.8	3.95	252.9	3.62
		AR806**	197.9	3.95	184.5	3.62
Maltby	Erwin Lake	SUB	518.6	Does Not Clear	424.0	3.05
		AR1128	414.4	3.95	338.8	3.62
Moonridge	Clubview	SUB	1105.7	3.73	666.6	3.56
		AR424**	655.2	3.95	389.8	3.62
	Goldmine	SUB	1185.6	4.68	699.2	3.56
		AR405**	1136.7	3.95	516.0	3.62
Radford	Radford	IR3470*	2727.4	6.00	n/a*	n/a*
Shay	Shay	IR3440*	2127.3	6.00	n/a*	n/a*
Village	Boulder	SUB	1720.2	3.02	1708.9	2.84
		AR102	1183.5	3.95	386.6	3.62
		AR105	610.4	3.95	332.1	3.62
	Lagonita	SUB	2043.3	2.98	2190.2	2.84
		AR145	758.6	3.25	674.2	2.91

*Baldwin, Radford and Shay 34.5 kV circuit are delta connected and do not have ground faults
**These devices are existing oil reclosers that may not offer ground protection. It is assumed in this case that the oil reclosers will be replaced with S&C IntelliRupters to allow fast tripping ground overcurrent protection.

Changing the pickup thresholds and setting fast curves to TCC 101/DT @ 6cy greatly reduces the clearing times for EOL faults. All protection devices using the TCC101 curve, with exception of the Erwin Lake Feeder recloser, would trip in less than 5.0 cycles (0.083 seconds) with the longest trip time being for the Goldmine Feeder recloser at 4.68 cycles (0.078 seconds).

8.6 Other Considerations

Fuse Changes

At present, BVES is installing current limiting fuses on all service transformers. These fuse types release less hot/burning material when clearing a fault when compared to the expulsion type fuses typically used. Also, if the fault current is greater than the current limiting rating the fuse design will actively limit the current. These fuses limit the overall energy of a fault and provide very fast clearing. The fast clearing times and current limiting capabilities will limit the required reach for the fast curve settings, effectively increasing the circuit coverage of the fast curve settings.

G&W Current Limiting Protector (CLiP)

The Current Limiting Protector is an electronically triggered actuator with a parallel current limiting fuse. The bus bar carries normal continuous current. When current exceeds a user settable threshold the bus bar is opened, allowing all fault current to pass through the current limiting fuse to blow and clear the fault. This method requires the interrupter to be replaced after use. However, clearing times can be significantly reduced to within half a cycle, and the fault let through energy is greatly limited (typically down to less than 1% compared to 5.0 cycle breakers). Extremely fast clearing times and limiting fault energy greatly reduces risk of wildfire ignition.

Downed Conductor Protection

Downed conductor conditions can be difficult to detect with normal distribution overcurrent protection. Downed conductors can be very high impedance faults (HIF), sometimes limiting fault currents to less than 100 A, which makes it difficult to distinguish from normal loads. Some relay manufacturers like SEL offer alternative high-impedance fault detection algorithms. SEL's HIF detects electrical arcing, by monitoring the current at harmonic frequencies. The relay "tunes" to the normal harmonics measured on the line over time and compares that profile to detect harmonic abnormalities caused by HIF arcing, such as can occur with downed conductors.

Other system wide technologies can be applied to detect broken conductors. Voltage monitoring can be implemented at either end of main feeder lines to detect if a single phase has been opened. These systems typically require systems communications to compare measurements between devices at multiple locations.

9. CONCLUSIONS

The final results of the study found that 11 of 18 protection devices under consideration do not have fast curve settings that cover 100% of the overhead line conductors within their zones when using typical protection margins. Nine (9) protection devices covered only 50% or less of the overhead conductors in their zone. The result of the reduced coverage is long clearing times at the end of zones of protection.

BVES has 25 circuits that traverse high fire risk areas. If the results of this study were translated to the remaining circuits, about 72% of protection devices would have 90% or more circuit coverage for phase faults and only 39% of protection devices would have 90% or more circuit coverage for ground faults. For phase faults, 11% of protection devices would have less than 50% circuit coverage, and 50% of protection devices would have less than 50% circuit coverage for ground faults. Only 28% of protection devices would have full 100% circuit coverage for both phase and ground faults. To have a protection scheme that will cover 100% of the required circuit the settings will need to be set more sensitively to extend the circuit coverage.

Note, existing protection was evaluated for coverage under normal conditions. In this case the protection zones did not overtrip fuses and Tripsavers. When using system normal protection zones 11 of the 18 devices do not cover their entire zones given typical protection margins. Four (4) of these device issues could be resolved by adding ground protection. It is highly recommended BVES evaluate existing "normal" protection to ensure it meets BVES protection criteria.

This study proposes an Enhanced Power Line Safety Setting (EPSS) philosophy that can be found in appendix A, and an EPSS Implementation Strategy that can be found in appendix B. Implementing the changes outlined in this report will increase protection reaches to 100% circuit coverage for nearly all circuits and decrease EOL fault trip times to below 6.0 cycles. This provides wildfire mitigation protection that is comparable to the strategies of the other industry utilities previously discussed.

Many of the observed coverage issues are caused by ground elements not being sensitive enough or not being programed altogether. Ground overcurrent protection should be enabled on all 4.16 kV distribution circuits. This may require replacing oil reclosers with more modern electronic reclosers that offer ground protection.

Changing the fast curve pickups to 150% of peak load for phase elements, and 30% of peak load for ground elements at the substation feeder reclosers will yield 100% protection zone coverage for eight (8) of the ten (10) substation devices. If load imbalance data becomes available, the ground element should be set greater than 150% of peak load imbalance at each device. Additionally, load data at the line reclosers should be evaluated for adequate load security.

Not all devices have “fast” curves programmed, and programmed curves were not consistent between devices. A “fast” curve should be standardized across all devices. The TCC 101 should be used across all 4kV devices for fast tripping. This curve is already being used by some of the protective devices in BVES’s system. The 101 curve has a flat profile and provides fast trip times for all points on the curve.

The pickup settings and curve changes did not consider coordination with other devices or other distribution protection considerations such as conductor thermal loading, or cold load pickup. Using a smaller pickup than what has been recommended is acceptable for wildfire mitigation, as it will only make the element more sensitive and provide faster clearing times. However, without knowing BVES normal distribution protection philosophy it is difficult to understand how this wildfire mitigation plan would affect BVES’s normal protection goals. Therefore, it cannot be recommended to replace the normal protection settings without further analysis.

If BVES wishes to maintain separate slow protection, or more sensitive pickups with slow operation the wildfire fast protection can be programmed as a definite time element. The Form 6 controllers share the same minimum trip setting for both fast and slow curves. It will not allow separate minimum trip setting for each curve. Neither the IntelliRupter or Form 6 will allow the first curve (fast) trip to time concurrently with the second (slow) trip. If BVES desires to have the wildfire fast trip with a higher pickup than the normal protection curves, then the fast curve can be programed as a definite time overcurrent element with a 6.0 cycle delay. In the Form 6 controllers this can use the High Current Trip element. In the IntelliRupters this can be programmed as the Definite Time 1 element. This will allow the definite time element to time concurrently with the normal time overcurrent elements, providing a more complex protection profile that will not lose normal protection sensitivity.

Since wildfire fast curve settings did not consider cold load, it is suggested to disable this when closing the breaker/recloser to reenergize the circuit after a fault event, and reenable once the line or line section has been successfully energized. This eliminates the potential for instantaneously tripping on cold load pickup.

APPENDIX A – EPSS PHILOSOPHY

The Enhanced Power Line Safety Setting (EPSS) is a wildfire mitigation protection strategy to be used during summer months when wildfire danger is high. The goal of this protection is to trip and clear faults as fast as possible on the entirety of the protected circuit. To do so, this protection sacrifices circuit coordination in favor of sensitivity and fast tripping. The EPSS protection should be set as follows:

- Reclosing
    - All reclosing attempts disabled. Devices will be single trip to lockout.
- Phase Sensitivity:
    - 1.5 times peak loading ≤ Minimum Phase Trip (Pickup) < EOL_{LL} /2 (50% protection reach margin)
- Phase Fast curve = TCC 101
- Ground Sensitivity:
    - 1.5 times peak load imbalance ≤ Minimum Ground Trip (Pickup) < EOL_{SLG} /3 (33% protection reach margin)
    - If load imbalance data is not available: Ground minimum trip > 30% of historical peak load phase current imbalance at the protection device.
- Ground Fast curve = TCC 101

When EPSS is active, the protection is made fast and more sensitive. To ensure full coverage of the fast trips the zone of protection must trip for faults beyond Tripsavers and fused sections of the circuit. End-of-Line (EOL) faults are the minimum fault values seen by the recloser or protective device on overhead line, including faults on downline overhead lines that are beyond fuses and Tripsavers. The zone of protection stops at other downline reclosers and transformers.

Since underground conductors are not susceptible to wildfire ignition, EOL faults beyond fuses and Tripsavers on undergound line segments can be ignored. However, if the underground line is not protected by a fuse, Tripsaver, or other protective device then the EOL faults must be included in the maximum trip thresholds.

Using the 101 time current curve ensures faults should clear within 12.0 cycles (0.2 seconds).

APPENDIX B – EPSS IMPLEMENTATION STRATEGY

This implementation strategy covers the rollout of EPSS protection on BVES system. In order to set up EPSS protection the following information is required:

- Short Circuit model able to provide short circuit fault values across the distribution system.
- A means of identifying all reclosers and feeder protection devices on distribution circuit.
  - Devices will need existing setting files and controller data.
  - Fuses and Tripsavers are not needed, but these should be included in the distribution model to help define the bounds of zones of protection.
- Peak phase load data at substations and reclosers.
- Peak load imbalance data at substations and reclosers.

To improve circuit coverage for fast tripping and sensitivity, implement the following device setting changes:

1) Enable ground overcurrent elements in any protection devices where the protection is available but turned off. This should be enabled on all 4.16 kV distribution circuits. This will allow much greater sensitivity for single line to ground faults.

2) Standardize and update fast curves across all 4.16kV devices. In "Summer" setting profiles, for the initial fast trip update the curves to the standardized TCC 101 curve. Special focus should be given to those devices that are presently using SEL U5 or inverse curves.

3) While updating the fast curves, it would be most efficient to also re-evaluate and update pickup settings per the criteria contained in the EPSS Philosophy.

4) Ensure reclose attempts are disabled in EPSS setting profile.

Having pickup setting flexibility and ground overcurrent protection is key for EPSS. Oil reclosers may not offer these capabilities. It is recommended to replace any oil recloser units with electronically controlled reclosers. The new reclosers should be three-phase units and offer ground overcurrent and negative sequence overcurrent protection. Means of adding definite time elements would also be beneficial. Electronically controlled reclosers may also have the benefit of recording and providing metering data. It is understood equipment lead times may prolong the replacement of oil reclosers. For temporary EPSS protection oil reclosers can be programmed with the A curve and be put in non-reclosing state. This will provide some fast clearing for phase faults. The next upstream electronically controlled recloser can have its ground overcurrent element set to overtrip the oil recloser until it is replaced.

For instances where device pickups cannot satisfy both protection reach margins and load security margins, consider installing an additional downline series recloser. The new recloser should shorten the zone of protection bringing the EOL fault location closer. The new recloser should also see a smaller peak load current, allowing it to have a more sensitive pickup.

Other methods and new technologies, as discussed previously, could be leveraged to continue to improve upon wildfire mitigation. Particularly in the area of detecting high impedance faults, electrical arcing, and downed conductors. However, implementing these methods would be costly and go beyond what other utilities are currently practicing.

APPENDIX C – EXISTING RELAY PROTECTION SETTINGS

TABLE 18: EXISTING PHASE PROTECTION SETTINGS							
SUBSTATION	**CIRCUIT**	**DEVICE / ZONE**	**TYPE/ CONTROLLER**	**PU**	**CURVE FAST/ SLOW**	**TIME DIAL FAST/ SLOW**	**TIME ADDER FAST/ SLOW**
Baldwin	Baldwin	IR3430	IntelliRupter	580	SEL U5	0.6	0
Bear City	Holcomb	SUB	IntelliRupter	560	S&C 102	1	0
Fawnskin	North Shore	SUB	Cooper VWE	570	102 / 114	1	0
		AR805	IntelliRupter	380	S&C 101	1	0
		AR806	McGraw/ Edison 6H	200	A / B	1	0
Maltby	Erwin Lake	SUB	Cooper VWE	580	101 / 132	1	0
		AR1128	IntelliRupter	200	S&C 101 / B	1	0
Moonridge	Clubview	SUB	IntelliRupter	560	SEL U5 / SEL U3	1 / 2.6	0 / 0
		AR424	RX	560	A / B	1 / 1	0 / 0
	Goldmine	SUB	IntelliRupter	560	SEL U5 / SEL U3	1 / 2.6	0
		AR405	McGraw/ Edison R	560	A / B	1	0
Radford	Radford	IR3470	IntelliRupter	170	SEL U3	1	0
Shay	Shay	IR3440	IntelliRupter	580	SEL U5	0.6	0
Village	Boulder	SUB	Pad recl / Form 6	640	101 / 116	1 / 1	0 / 0
		AR102	IntelliRupter	580	S&C 101	1	0
		AR105	IntelliRupter	380	S&C 101	1	0
	Lagonita	SUB	Padmount recl/Form 6	640	104 / 116	1	0
		AR145	Cooper NOVA?/ Form6	640	SEL U5	0.6	0

Where possible, settings are from “Summer” settings profiles.

TABLE 19: EXISTING GROUND PROTECTION SETTINGS							
SUBSTATION	CIRCUIT	DEVICE / ZONE	TYPE/ CONTROLLER	PU	CURVE FAST/ SLOW	TIME DIAL FAST/ SLOW	TIME ADDER FAST/ SLOW
Baldwin	Baldwin	IR3430	IntelliRupter	100	SEL U1	0.8	0
Bear City	Holcomb	SUB	IntelliRupter	280	S&C 106	1	0
Fawnskin	North Shore	SUB	Cooper VWE	340	106 / 141	1	0
		AR805	IntelliRupter	230	S&C 102	1	0
		AR806	McGraw/ Edison 6H	n/a	n/a	n/a	n/a
Maltby	Erwin Lake	SUB	Cooper VWE	300	106 / 135	1	0
		AR1128	IntelliRupter	n/a	n/a	n/a	n/a
Moonridge	Clubview	SUB	IntelliRupter	n/a	n/a	n/a	n/a
		AR424	RX	n/a	n/a	n/a	n/a
	Goldmine	SUB	IntelliRupter	n/a	n/a	n/a	n/a
		AR405	McGraw/ Edison R	n/a	n/a	n/a	n/a
Radford	Radford	IR3470	IntelliRupter	10	SEL U3	2	0
Shay	Shay	IR3440	IntelliRupter	100	SEL U1	0.8	0
Village	Boulder	SUB	Pad recl / Form 6	320	106 / 135	1	0
		AR102	IntelliRupter	260	S&C 106	1	0
		AR105	IntelliRupter	230	S&C 102	1	0
	Lagonita	SUB	Padmount recl/Form 6	370	106 / 135	1	0
		AR145	Cooper NOVA?/ Form6	370	106 / 135	1	0

Where possible, settings are from “Summer” settings profiles.

APPENDIX D – ZONE OF PROTECTION EOL FAULTS AND LOCATIONS

TABLE 20: ZONE OF PROTECTION EOL FAULTS AND LOCATIONS					
SUBSTATION	CIRCUIT	DEVICE / ZONE	FAULT TYPE	FAULT CURRENT (A)	FAULT LOCATION
Baldwin	Baldwin	IR3430	Three Phase Amps	1587.0	OH_65607
			PhPh Amps	1374.4	OH_65607
Bear City	Holcomb	SUB	Three Phase Amps	1061.0	OH_54055
			PhPh Amps	910.8	OH_54055
			Max PhGd Amps	651.4	OH_53837
			Max PhGd Amps A	651.4	OH_53837
			Max PhGd Amps B	686.4	OH_54057
			Max PhGd Amps C	757.6	OH_54000
Fawnskin	North Shore	SUB	Three Phase Amps	1665.4	OH_37106
			PhPh Amps	1442.3	OH_37106
			Max PhGd Amps	952.1	OH_50378
			Max PhGd Amps A	1192.1	UG_63262
			Max PhGd Amps B	952.1	OH_50378
			Max PhGd Amps C	1383.7	OH_62482
		AR805	Three Phase Amps	636.1	OH_62922
			PhPh Amps	283.8	OH_62471
			Max PhGd Amps	252.9	OH_62718
			Max PhGd Amps A	260.9	OH_62471
			Max PhGd Amps B	505.0	OH_62922
			Max PhGd Amps C	252.9	OH_62718
		AR806	Three Phase Amps	228.5	OH_62567
			PhPh Amps	197.9	OH_62567
			Max PhGd Amps	184.5	OH_62567
			Max PhGd Amps A	184.2	OH_62567
			Max PhGd Amps B	184.5	OH_62567
			Max PhGd Amps C	183.7	OH_62567
Maltby	Erwin Lake	SUB	Three Phase Amps	659.0	OH_46180
			PhPh Amps	518.6	OH_46648
			Max PhGd Amps	424.0	OH_60216
			Max PhGd Amps A	485.9	OH_46180
			Max PhGd Amps B	443.2	OH_46648
			Max PhGd Amps C	424.0	OH_60216
		AR1128	Three Phase Amps	478.6	OH_51093
			PhPh Amps	414.4	OH_51093
			Max PhGd Amps	338.8	OH_51125

TABLE 20: ZONE OF PROTECTION EOL FAULTS AND LOCATIONS					
SUBSTATION	CIRCUIT	DEVICE / ZONE	FAULT TYPE	FAULT CURRENT (A)	FAULT LOCATION
			Max PhGd Amps A	344.7	OH_51093
			Max PhGd Amps B	344.7	OH_51093
			Max PhGd Amps C	338.8	OH_51125
Moonridge	Clubview	SUB	Three Phase Amps	1276.8	OH_900011
			PhPh Amps	1105.7	OH_900011
			Max PhGd Amps	666.6	OH_6695
			Max PhGd Amps A	666.6	OH_6695
			Max PhGd Amps B	922.9	OH_900011
			Max PhGd Amps C	835.9	OH_8357
		AR424	Three Phase Amps	756.5	OH_7409
			PhPh Amps	655.2	OH_7409
			Max PhGd Amps	389.8	OH_8056
			Max PhGd Amps A	496.4	OH_15059
			Max PhGd Amps B	488.2	OH_20764
			Max PhGd Amps C	389.8	OH_8056
	Goldmine	SUB	Three Phase Amps	1369.0	OH_21432
			PhPh Amps	1185.6	OH_21432
			Max PhGd Amps	699.2	OH_4761
			Max PhGd Amps A	699.2	OH_4761
			Max PhGd Amps B	729.1	OH_5674
			Max PhGd Amps C	1103.8	OH_21432
		AR405	Three Phase Amps	1329.7	OH_5718
			PhPh Amps	1136.7	OH_5718
			Max PhGd Amps	516.0	OH_21640
			Max PhGd Amps A	942.3	OH_5729
			Max PhGd Amps B	614.2	OH_6152
			Max PhGd Amps C	516.0	OH_21640
Radford	Radford	IR3470	Three Phase Amps	3149.3	UG_59620
			PhPh Amps	2727.4	UG_59620
Shay	Shay	IR3440	Three Phase Amps	2456.6	OH_21066
			PhPh Amps	2127.3	OH_21066
Village	Boulder	SUB	Three Phase Amps	1986.3	OH_42352
			PhPh Amps	1720.2	OH_42352
			Max PhGd Amps	1708.9	OH_42352
			Max PhGd Amps A	1708.9	OH_42352
			Max PhGd Amps B	1708.9	OH_42352
			Max PhGd Amps C	1708.9	OH_42352
		AR102	Three Phase Amps	1366.6	OH_42838

TABLE 20: ZONE OF PROTECTION EOL FAULTS AND LOCATIONS					
SUBSTATION	CIRCUIT	DEVICE / ZONE	FAULT TYPE	FAULT CURRENT (A)	FAULT LOCATION
			PhPh Amps	1183.5	OH_42838
			Max PhGd Amps	386.6	OH_42579
			Max PhGd Amps A	939.4	OH_42624
			Max PhGd Amps B	1065.2	OH_42539
			Max PhGd Amps C	386.6	OH_42579
		AR105	Three Phase Amps	715.3	OH_16264
			PhPh Amps	610.4	OH_16264
			Max PhGd Amps	332.1	OH_42537
			Max PhGd Amps A	484.3	OH_42590
			Max PhGd Amps B	491.5	OH_42858
			Max PhGd Amps C	332.1	OH_42537
	Lagonita	SUB	Three Phase Amps	2359.4	OH_9452
			PhPh Amps	2043.3	OH_9452
			Max PhGd Amps	2190.2	OH_9452
			Max PhGd Amps A	2190.2	OH_9452
			Max PhGd Amps B	2190.2	OH_9452
			Max PhGd Amps C	2190.2	OH_9452
		AR145	Three Phase Amps	1000.4	OH_27530
			PhPh Amps	758.6	OH_10599
			Max PhGd Amps	674.2	OH_10599
			Max PhGd Amps A	674.2	OH_10599
			Max PhGd Amps B	764.3	OH_27530
			Max PhGd Amps C	674.2	OH_10599

APPENDIX E – BVES PROVIDED CIRCUIT PEAK LOAD DATA

TABLE 21: CIRCUIT PEAK LOAD DATA

SUBSTATION	CIRCUIT	DEVICE	PEAK LOAD 3PH KVA	PEAK LOAD PHASE (A)
Baldwin	Baldwin	IR3430	19,533	366.92
Bear City	Holcomb	SUB	1,649	269.22
Fawnskin	North Shore	SUB	1,883	283.84
Maltby	Erwin Lake	SUB	2,896	491.40
Moonridge	Clubview	SUB	1,648	303.46
	Goldmine	SUB	Not provided	496.00
Radford	Radford	IR3470	8,799	165.14
Shay	Shay	IR3440	28,063	497.84
Village	Boulder	SUB	2,985	460.09
	Lagonita	SUB	3,320	514.08