Electrical Services & Systems
711 Kapiolani Boulevard, Suite 930
Honolulu, HI 96813

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SUBMITTED BY: NACIONAL

SHORT CIRCUIT STUDY
PROTECTIVE DEVICE COORDINATION STUDY
ARC FLASH HAZARD ANALYSIS
FOR
MOLOKAI IRRIGATION SYSTEM
WAIKOLU TUNNEL
MOLOKAI, HAWAII

REVISION 1
MARCH 2015

1.0 EXECUTIVE SUMMARY

This report contains the results of analysis performed on the electrical distribution system for the Molokai Irrigation System facility, Molokai, HI. This revision was released to update the fault current at MCC-FARRINGTON, 11-MAIN plot and cable size updated between East Portal and Diversion Dam building. The purpose of this study is to evaluate the existing electrical system, as detailed below.

The executive summary contains the description and guide to the rest of the report. In addition, it also contains the recommendations of the entire study.

1.1 Objectives

1. <u>Short-Circuit Study</u>

Perform a short-circuit study on the existing electrical distribution system shown in order to determine the available fault current at pertinent locations throughout the distribution system. The scope of the study includes:

- Analysis begins at the incoming 12.47 kV utility service, continues through the medium and low voltage substations, and ends at the low voltage panelboards and motor control centers shown in contract drawing E4.5 & E-4.2.

The available fault currents determined by the short-circuit study will be used in the coordination and device evaluation analysis.

2. <u>Equipment Evaluation</u>

Evaluate the short-circuit ratings of protective devices and other distribution equipment found at the locations shown in drawing E-4.5 & E-4.2.

3. <u>Coordination Study</u>

Review the existing system overcurrent protection and coordination. Where applicable, provide suggestions for improvement.

4. <u>Arc Flash Analysis</u>

Perform an arc flash hazard analysis per NFPA 70E on the electrical distribution system described in item #1 above.

5. <u>Recommendations</u>

Provide specific recommendations for improving the electrical distribution system performance and correcting any deficiencies found by the studies.

1.2 Results

1. Short-Circuit Study

Short-circuit currents were calculated for each bus shown on the one-line diagram in Appendix D.

The following upstream available fault current information was provided by Maui Electric Company (MECO) utility:

Location: 12.47 kV MECO H-FRAME

- Three-phase and single-line-to-ground fault current: 3,300 A with assumed X/R=8

Location: 480V T-FARRINGTON SEC

- Three-phase and single-line-to-ground fault current: 14,800 A with assumed X/R=8

A copy of the letter/email provided by MECO utility can be found for review in Appendix C.

Short-circuit currents were calculated for a three-phase bolted fault and single-line-to-ground fault at each bus shown on the one-line diagram found in Appendix D. The system was modeled for worst-case fault currents.

The following short-circuit study cases were evaluated:

- Study Case No. 1 – Normal Source

See Section 2, Appendix A and Appendix B for more information.

2. Equipment Evaluation

The Equipment Evaluation is based on the power system worst-case short-circuit current configuration.

The short-circuit ratings of protective devices and other distribution equipment are evaluated in Section 2, Table 2.1.

In summary of Table 2.1, no equipment was found to be applied beyond its design ratings.

3. Coordination Study

The time-current coordination plots of the protective overcurrent devices are shown in Section 3. In developing the device settings, consideration was given to both isolation of faults, protection of cables, and protection of transformers.

Efforts were made to provide the best coordination possible with the existing protective devices. It should be understood that selective coordination between two instantaneous trip units cannot be achieved for fault levels above the instantaneous pickup of the upstream device. There is some overlapping of curves that cannot be avoided.

The system coordination began at the 12.47 kV utility fuses, and continued downstream through medium voltage vacuum fault interrupters and ends at the largest feeder breaker at each panelboard and motor control center.

In summary of the coordination study, the recommended protective device settings would maximize coordination while maintaining adequate protection.

See Section 3 for more information and Section 4 for device settings.

4. <u>Suggested Protective Device Settings</u>

Settings for the protective devices are shown in Section 4.

Each entry references a coordination plot number found in Section 3. The referenced plot illustrates the coordination of the listed device with the relevant "upstream" and "downstream" protective devices. The protective devices listed in Section 4 should be set per the suggested settings.

5. <u>Arc Flash Analysis</u>

Details of the arc flash analysis are shown in Section 5. This arc flash hazard analysis of the Molokai Irrigation System in Molokai, HI required energy and boundary calculations for approximately nine (9) locations. In summary of Section 5, the incident energy calculated was found within acceptable levels.

Please note for this study, the arc flash hazard has been calculated but not the risk. The risk associated with performing energized electrical work will vary based on the work being performed as well as the condition of the equipment and other factors that can be best determined by a qualified person.

See Table 5.1 for a complete arc flash summary. **Note that the incident energy values listed in Table 5.1 are only valid after the recommended protective device settings shown in Section 4 have been implemented.**

1.3 Recommendations

1. <u>Marginal Equipment</u>

SWBD DIVERSION received a "Marginal" status, which means the device is at or above the 85% of its rated kAIC rating. Caution should be used when adding motor load, decreasing feeder length, increasing feeder size or any action that may increase the available fault current at this location. Increasing the fault current at this location may cause the equipment to become overdutied.

2. <u>Recommended Settings</u>

Adjustable protective device settings should be set according to the settings tables provided in Section 4.

3. <u>Reducing Incident Energy Levels</u>

The calculated incident energy at a particular location is dependent on three main factors: short-circuit current, distance, and time. These three factors directly affect the incident energy in the following manner:

Short-circuit current: The short-circuit current for a given power system is dependent on the system impedance and source fault current, and cannot be easily reduced.

Distance: IEEE Std 1584™-2002 provides a table with typical working distances. Increasing the working distance reduces the amount of incident energy that reaches the worker; however it becomes difficult to perform many work tasks with an increased working distance, therefore, this is not an optimal solution for most cases.

Time: The incident energy decreases when reducing the exposure time of the arc. This exposure time is directly related to the clearing time of the protective device(s) which feed the fault location.

Based on the preceding summary, arc flash mitigation techniques are most effective and feasible when they involve reducing the arc exposure time. In many locations, the setting of the protective device can be adjusted in order to decrease the interrupting time, resulting in decreased incident energy. However, in this study, settings for protective devices have not been adjusted to reduce incident energy if the chance of nuisance trips within critical circuits is introduced.

The other option involving reducing the arc exposure time is to consider equipment modifications and upgrades. Several solutions include upgrading trip units, installing “maintenance switches”, and using relays with multiple settings groups. Each specific location needs to be analyzed to determine which reduction method is best employed.

4. Testing and Preventative Maintenance

It is recommended that regularly scheduled testing and preventative maintenance be performed to ensure that the electrical distribution equipment continues to perform at an optimum level. Testing should entail primary injection testing of all power circuit breakers to verify proper tripping ranges, contact resistance testing, insulation resistance testing and complete switchgear and transformer cleaning and inspection.

5. Periodic Arc Flash Analysis Review

The 2012 edition of NFPA 70E includes several new requirements regarding arc flash hazard analysis. One new requirement found in Article 130 is that an arc flash hazard analysis must be updated:

- Every five years (at minimum)
- When the electrical system is modified or renovated in any way, including renovations, additions, or subtractions to the system

It is recommended that a plan is implemented to schedule a review of the arc flash hazard analysis for Molokai Irrigation System facility in a period not to exceed five years, and that a review is performed whenever substantial modifications or renovations take place.

6. Predictive Diagnostics Using Continuous Partial Discharge Measurements

Eaton recommends conducting Continuous Partial Discharge measurements on most medium voltage power transformers, bus ducts, switchgear, motors, generators, terminations, and splices of transmission and distribution cables. Partial Discharge (PD) analysis is a non-invasive, online method of collecting, filtering, and evaluating PD occurring in electrical apparatus. The goals are:

- To detect partial discharges as a result failing or compromised insulation
- To analyze the partial discharge activity, and if an insulation defect is detected:
    a. Make conclusions as to the severity of the defect.
    b. Advise as to possible defect locations and possible cause(s) of the defect.
    c. Advise as to urgency of inspection.
    d. Suggest preventive measures both immediate and long term.

Electrical insulation is very important to monitor as it defines a major item in the reliability of electrical machines. Continuous Partial Discharge on-line monitoring using the Eaton InsulGard™ is the most sensitive and reliable method for detecting failing insulation. PD monitoring when used in conjunction with Eaton's RM™ system offers customers the added benefit of prompt expert analysis and recommendation.

2.0 SHORT-CIRCUIT ANALYSIS

The short-circuit study determines the fault currents that flow in the system during various fault conditions. The calculated fault currents are used in the device evaluation and coordination studies. See Appendix A and Appendix B for the computer generated input data and output data. NEC-2011, Article 110.24(A) requires that service entrance equipment is labeled with the following pieces of information:

- Maximum available fault current
- Date on which the fault current was calculated

Article 110.24(B) adds that if there is a modification that may change this fault current value, it must be recalculated. The field marking must be updated to reflect the new value of maximum fault current.

The short-circuit calculations were done using A_FAULT, a computer software package by SKM Systems Analysis. The short-circuit analysis performed by A_FAULT is based on IEEE Std C37.010™-1999, IEEE Std C37.5™-1979, and IEEE Std C37.13™-2008.

Separate “Z” (complex), “X” (reactive), and "R" (resistive) networks are used by A_FAULT for the short-circuit analysis. A_FAULT uses complex network reduction and the relationship E/Z to calculate the fault current magnitude and angle at each faulted bus. The complex equivalent circuit impedance, Z, is calculated by the reduction of the “Z” (complex) network, and is reported as the “EQUIV. IMPEDANCE” in the A_FAULT reports. The X/R ratios calculated for each fault condition are based on the separate reduction of the X and R networks. These X/R ratios are used for the calculation of fault duty multipliers, to evaluate the short-circuit ratings of system components.

A_FAULT is capable of generating three types of short-circuit reports for both balanced (three-phase bolted) and unbalanced (line-to-ground) faults. The reports that are generated depend on the system that is being evaluated.

The three types of short-circuit reports are:

- Fault Report (for low voltage)
- Momentary Duty Report (for medium voltage)
- Interrupting Duty Report (for medium voltage)

1. <u>Fault Report</u>

The fault currents reported in the “Fault Report” are applicable to low voltage devices and components. The fault currents calculated in this report are based on the contribution data derived from IEEE Std C37.13-2008. The fault currents are calculated as follows:

- Motor and generator subtransient reactance values (Xd”) are adjusted per the first cycle duty multipliers described in IEEE Std 141™-1993 (Red Book).
- The complex equivalent circuit impedance, Z, is calculated by network reduction of the “Z” (complex) network.
- The momentary symmetrical current = E/Z.
- The X/R ratio is equal to the equivalent circuit reactance, X, divided by the equivalent circuit resistance, R. As discussed above, X is calculated by the reduction of the “X” (reactive) network and R is calculated by the reduction of the “R” (resistive) network.

Multiplying factors are determined, and used to adjust the calculated symmetrical fault current. The adjusted current is used to evaluate low voltage protective devices. Low voltage output algorithms and output reports reflect NEMA AB-1 molded case breaker de-rating multipliers. Breakers are de-rated for circuits where the power factor is lower than the NEMA test circuit (higher X/R ratio). The multipliers adjust the symmetrical fault current to the value associated with the systems fault point X/R ratio. The adjusted value listed on the report may then be compared directly with the manufacturer's published interrupting rating.

2. <u>Momentary Duty Report</u>

The “Momentary Duty Report” contains the calculated fault currents that occur during the first half-cycle of the fault. The momentary fault currents are used to evaluate medium and high voltage fuses, and the “closing and latching” capability (momentary rating) of medium and high voltage breakers. The fault currents reported in the “Momentary Duty Report” are calculated as follows:

- Motor and generator subtransient reactance values (Xd”) are adjusted per the first cycle duty multipliers described in IEEE Std 141-1993 (Red Book).
- The complex equivalent circuit impedance, Z, is calculated by network reduction of the “Z” (complex) network.
- The momentary symmetrical current = E/Z.
- The X/R ratio reported is equal to the equivalent circuit reactance, X, divided by the equivalent circuit resistance, R. As discussed above, X is calculated by the reduction of the “X” (reactive) network and R is calculated by the reduction of the “R” (resistive) network.
- A_FAULT calculates and reports the momentary asymmetrical current in two different ways, once as “sym*1.6” and again as “momentary based on X/R”. The “sym*1.6” value is the momentary symmetrical current multiplied by 1.6. The “momentary based on X/R” value is the momentary symmetrical current multiplied by

$$\sqrt{1+2e^{(-2\pi/(X/R))}}$$

3. Interrupting Duty Report

The fault currents reported in the "Interrupting Duty Report" are used to evaluate the interrupting rating of medium- and high-voltage breakers. The interrupting symmetrical current is calculated as follows:

- Motor and generator subtransient reactance values (Xd") are adjusted per the interrupting duty multipliers described in IEEE Std 141-1993 (Red Book).
- The complex equivalent circuit impedance, Z, is calculated by network reduction of the "Z" (complex) network.
- The interrupting symmetrical current = E/Z.
- The X/R ratio reported is equal to the equivalent circuit reactance, X, divided by the equivalent circuit resistance, R. As discussed above, X is calculated by the reduction of the "X" (reactive) network and R is calculated by the reduction of the "R" (resistive) network.
- A_FAULT uses the calculated X/R ratio to determine the minimum contact parting time multiplying factors for 2, 3, 5, and 8 cycle breakers. The multiplying factors are based on IEEE Std C37.5-1979 and IEEE Std C37.010-1999 standards. The multiplying factors are applied to the interrupting symmetrical current in order to calculate the RMS short-circuit current interrupting duty for 2, 3, 5, and 8 cycle breakers. This duty is compared to the symmetrical current interrupting rating of the circuit breaker. NACD (No AC Decrement) ratios are calculated with consideration of generator "Local" and "Remote" contributions as outlined in IEEE Std C37.010-1999.
- Motor and generator impedance multipliers for the short-circuit calculations are summarized in the following table. This is based on the recommended combination network for comprehensive multi-voltage system calculations (from IEEE Std 141-1993; Red Book):

Machine Type	Impedance (First Cycle Duty)	Impedance (Interrupting Duty)
Turbine generators, Condensers, Hydrogenerators with amortisseur windings	1.0 Xd"	1.0 Xd"
Synchronous motors	1.0 Xd"	1.5 Xd"
Induction motors > 1000 hp at speed ≤ 1800 RPM, or > 250 hp at 3600 RPM.	1.0 Xd"	1.5 Xd"
Induction motors ≥ 50 hp not covered above.	1.2 Xd"	3.0 Xd"
Induction motors < 50 hp	1.67 Xd"	Neglect

Note: Xd" is the subtransient reactance of the rotating machine.

2.1 Short-Circuit Objectives

The objective of the short-circuit analysis is to calculate the maximum short-circuit currents produced by balanced three-phase and unbalanced faults at each bus shown on the one-line diagram in Appendix D.

2.2 System Modeling

Short-circuit currents were calculated for a three-phase bolted fault and single-line-to-ground fault at each bus shown on the one-line diagrams found in Appendix D. The system was modeled for worst-case fault currents.

1. Cases:

The following short-circuit study cases were evaluated:

- Study Case No. 1 – Normal Source

2. Utility Information:

The following upstream available fault current information was obtained from Mr. Keith Sakamoto at MECO utility on September 13, 2012 via email.

Location: 12.47 kV MECO H-FRAME & T-FARRINGTON PRI

- Three-phase and single-line-to-ground fault current: 3,300 A with assumed X/R=8

Location: 480V T-FARRINGTON SEC

- Three-phase and single-line-to-ground fault current: 14,800 A with assumed X/R=8

A copy of the letter/email provided by MECO utility can be found for review in Appendix C.

3. System Information:

Input data used in this study was obtained from the following sources:

- Contract drawings E-4.5 & E-4.2
- Fopco Inc
- MECO

4. Assumptions:

The following assumptions were used in modeling the power system, and ensure conservative, worst-case results:

- An X/R ratio of 8.0 was used to model utility fault contributions.
- All motors were assumed to be running.
- Motor subtransient reactance is assumed to be 17%.
- System voltage is modeled at 100% nominal.
- T-225kVA transformer fuse is assumed to be S&C, SM-4, 15E
- T-300kVA FS transformer fuse is assumed to be Cooper, 353C10, 25E
- T-F (Farrington) transformer fuse is assumed to be Cooper, N-Tin, 10N

Complete information regarding the system model used for the computer simulation is included in Appendix A.

2.3 Short-Circuit Results

The results of the short-circuit analysis, including calculated branch contributions, are provided in Appendix B. The one-line diagram with referenced bus identification is included in Appendix D.

2.4 Equipment Evaluation

The purpose of the equipment evaluation is to compare the ***maximum*** calculated short-circuit currents to the short-circuit ratings of protective devices. The comparison is made in order to determine if the device can interrupt or withstand the available fault currents of the electrical system to which the device is applied, as required by NEC-2011, Article 110.9 and NEC-2011, Article 110.10. The device evaluation follows the evaluation procedures outlined in IEEE Std C37.13-2008, IEEE Std C37.010-1999, IEEE Std C37.5-1979, IEEE Std C37.41™-2008, IEEE Std 1015™-2006 (Blue Book), and applicable ANSI, NEMA, and UL standards.

The results of the short-circuit equipment evaluation are summarized in Table 2.1. The table indicates “Bus I.D.” (corresponds to bus designations used in the one-line diagram of Appendix D), “Manufacturer”, “Status” (Pass, fail, unknown, or marginal), “Type” (equipment category), “Equip Volts”, calculated short-circuit duty, the equipment short-circuit rating, the series rating (if applicable), and the maximum duty rating.

The maximum duty rating is calculated by:

$$\frac{S.C.duty}{DeviceS.C.Rating} \times 100$$

For equipment with series ratings, the maximum duty rating is calculated using the series rating instead of the individual device short-circuit rating. All short-circuit current values are reported in units of kA.

1. For low voltage devices:

The calculated short-circuit duty is reported under “Calc Isc (kA)" and the device short-circuit rating is reported under "Equip Isc (kA)". The calculated duty has been adjusted accordingly per the system X/R and device test X/R.

2. For medium/high voltage breakers:

The calculated *interrupting* short-circuit duty is reported under "Calc Isc (kA)" and the breaker short-circuit interrupting rating is reported under "Equip Isc (kA)". The interrupting duty has been adjusted per multiplying factors based on the breaker clearing time and system X/R. The calculated momentary duty (i.e. close-and-latch duty) is reported under "Calc Mom (kA)". The breaker momentary (i.e. close-and-latch) rating is reported under "Equip Msc (kA)".

3. For medium/high voltage fuses, switches, and motor starters:

The calculated *momentary symmetrical* short-circuit duty is reported under "Calc Isc (kA)" and the device's momentary symmetrical short-circuit rating is reported under "Equip Isc (kA)". The calculated *momentary asymmetrical* duty is reported under "Calc Mom (kA)". The device's momentary asymmetrical short-circuit rating is reported under "Equip Mom (kA)".

Table 2.1 - Equipment Evaluation

Bus I.D.	Manufacturer	Status	Type	Bus Voltage (V)	Calc Isc (kA)	Equip Isc (kA)	Rating %	Calc Mom (kA)	Equip Mom (kA)	Rating %
MCC-FARRINGTON	ALLEN-BRADLEY	Pass	LV MCC	480	14.04	35.00	40.12			
PNL P	SQUARE D	Pass	LV PANEL	208	0.63	10.00	6.30			
PNL W	CUTLER-HAMMER	Pass	LV PANEL	208	0.64	10.00	6.36			
SW-1	COOPER	Pass	MV VFI	12470	3.36	12.00	28.02	4.74	20.00	23.68
SWBD DIVERSION	WESTINGHOUSE	Pass	LV SWITCHBOARD	480	13.95 (*N1)	14.00	99.63			
SWBD-300KVA	SQUARE D	Pass	LV SWITCHBOARD	480	7.23 (*N1)	14.00	51.63			
T- 500KVA PRI	COOPER	Pass	MV VFI	12470	1.54	12.00	12.82	1.62	20.00	8.11
T-225KVA PRI	G&W Electric	Pass	MV VFI	12470	1.71	12.50	13.66	1.80	20.00	9.02
T-225KVA SEC	Eaton	Pass	LV Breakers	480	6.13 (*N1)	10.00	61.33			
T-300KVA PRI	COOPER	Pass	MV VFI	12470	1.65	12.00	13.78	1.75	20.00	8.73
WELL22 CNTLR	SQUARE D	Pass	LV BREAKER	480	5.02 (*N1)	18.00	27.90			

(*N1) System X/R higher than Test X/R, Calc Isc kA modified based on low voltage factor.

3.0 PROTECTIVE DEVICE COORDINATION STUDY

The protective device coordination study determines overcurrent protective relay and circuit breaker settings in order to provide an optimal compromise between protection and selectivity.

The coordination plots were developed using SKM System Analysis' CAPTOR software. Protective device coordination was performed in accordance with IEEE Std 242™-2001 (Buff Book). Minimum guidelines for equipment protection, as outlined in the National Electrical Code (NEC) and applicable standards of the American National Standards Institute (ANSI), were followed.

3.1 General Description and Protection Philosophy

Using the appropriate maximum fault currents, the time-current coordination curves were plotted as operating time versus current magnitudes to show protective device tripping and/or clearing characteristics and coordination among these devices.

Consideration was given to provide both selective isolation of faults and maximum protection of equipment such as cables, transformers, motors, etc.

To achieve the optimum protection and selectivity, the following guidelines were followed throughout the study:

1. Ideally, the settings of any overcurrent device should be high enough to permit the continuous full-load operating capacity of the cables and the equipment they supply, and to ride through system temporary disturbances such as in-rush current. On the other hand, the settings should be low enough to provide overload and short-circuit protection under minimum fault conditions.
2. Considering any two protective devices in series:
   - The maximum available fault current at the downstream device determines the upper limit of the coordination range between these two devices.
   - The minimum available fault current at the downstream device or the pick-up setting of the upstream device determines the lower limit of the coordination range.
   - Series instantaneous devices do not coordinate unless there is sufficient impedance between the two devices.
   - When plotting coordination curves, certain time intervals must be maintained between the curves in order to ensure correct selectivity. These time intervals vary, depending on the device types. In general, however, the following must be taken into consideration when determining the appropriate time separation interval: Breaker clearing

time, relay tolerances, induction disk over-travel, and a reasonable safety margin for error.

3.2 Codes and Standards

The minimum protection requirements as outlined in the National Electric Code (NEC), ANSI, and IEEE Standards were used as guidelines for protective device settings.

3.3 Coordination Objectives

Review the existing system overcurrent protection and coordination. Provide suggestions for improvement.

3.4 Coordination Results

The system coordination began at the 12.47 kV utility fuse, and continued downstream through the medium voltage vacuum fault interrupters and ends at the largest feeder breaker at each panelboard and motor control center.

As shown on the time-current plots, each device curve is tagged with an arrow and label referencing its location on the plot's individual representative one-line diagram. This label also references the device to its' specific manufacturer information, including ratings and settings, as indicated in the text box on each plot. The device time-current characteristics are truncated at maximum through-fault current for a downstream fault.

Efforts were made to provide the best coordination possible with the protective devices supplied under this contract. Areas where breaker trip curves overlap indicate areas of possible non-selective breaker operation. Where possible, efforts were made to reduce non-selective breaker operation while maintaining adequate system protection. In some cases, because of device limitations, little can be done to improve device selectivity. Such device limitations include the fixed operating characteristic of a fuse, the built-in instantaneous or instantaneous “over-ride” elements of molded case circuit breakers, and the limited instantaneous trip range of trip units with an instantaneous trip function.

In cases involving redundant protective devices, non-selective breaker operation is of little or no concern. Protective devices are redundant if, regardless of which device opens, the same system outage occurs. Often, in order to improve overall system protection and coordination, redundant devices are intentionally set to overlap (i.e. non-selectively coordinate with) one another.

Adequate coordination is achieved using the recommended protective devices, with settings and ratings as listed in Section 4. The recommended adjustments would maximize coordination in an attempt to allow the various downstream devices to isolate faults without operation of the upstream devices. Although instantaneous trip devices provide the highest degree of protection, when applied in series they compromise selectivity at high-magnitude fault currents.

3.5 Coordination Recommendations

All of the adjustable low voltage electronic trip and thermal magnetic circuit breakers and medium voltage equipment should be tested and adjusted according to the recommended settings given in Section 4.

The following deficiencies were noted:

1. Phase coordination between the utility fuse and downstream VFI switch overlaps around the instantaneous region. This lack of coordination is not avoidable due to the fixed trip characteristics of the utility fuse as well as limited adjustable settings available from the VFI. The instantaneous trip element of the VFI should provide adequate coordination at maximum fault current.

   Lack of coordination between device SW-1 VFI and T-225kVA VFI exists which could result in service interruption downstream of device SW-1 VFI. Adjusting the T-225kVA VFI settings should improve system coordination and protection, but this slight coordination improvement achieved could still present these two devices to mis-coordinate. This is due to the close timing interval between these devices that could cause operation of either device to race in the event of a fault. Refer to plot 01-UTIL R for the recommended settings and 01-UTIL for the as found settings for details.

2. Lack of coordination between ground fault device T-225kVA VFI and SW-1 VFI exists due to the inherent tripping characteristics of each device. Even with settings adjustment made to improve coordination, evidence of lack of coordination still exists at above 120A of ground fault. Should improve coordination is desired, replacing the VFI with a breaker relay combination may be of importance. Refer to plot 02-UTIL G R for the recommended settings and 02-UTIL G for the as found settings for details.

3. As discussed in item 1 above with regards to lack of coordination between SW-1 VFI and downstream devices due to their tight intervals, settings adjustment is necessary to improve system selectivity and protection. Although coordination is somewhat improved with these settings, lack of coordination still exists. These lack of coordination are not avoidable due to the limited available options of the VFI settings. Refer to plot 03-T300kVA VFI R for the recommended and 03-T300kVA VFI for the as found settings for details.

4. Similar ground fault protection coordination issues as discussed in item 2 above is also evident between device T-225kVA VFI, T-300kVA VFI and T-500kVA VFI. For device T-300kVA VFI and T-500kVA VFI, these as found ground fault settings are already set at minimum (just above nuisance tripping level); however, lack of coordination with upstream T-225kVA VFI device is not avoidable due to the tripping characteristics of each device. Should improve coordination is desired, replacing the VFI

with a breaker relay combination may be of importance. Refer to plot 04-T300kVA VFI G R for the recommended plot and 04-T300kVA VFI G for the as found plot for details.

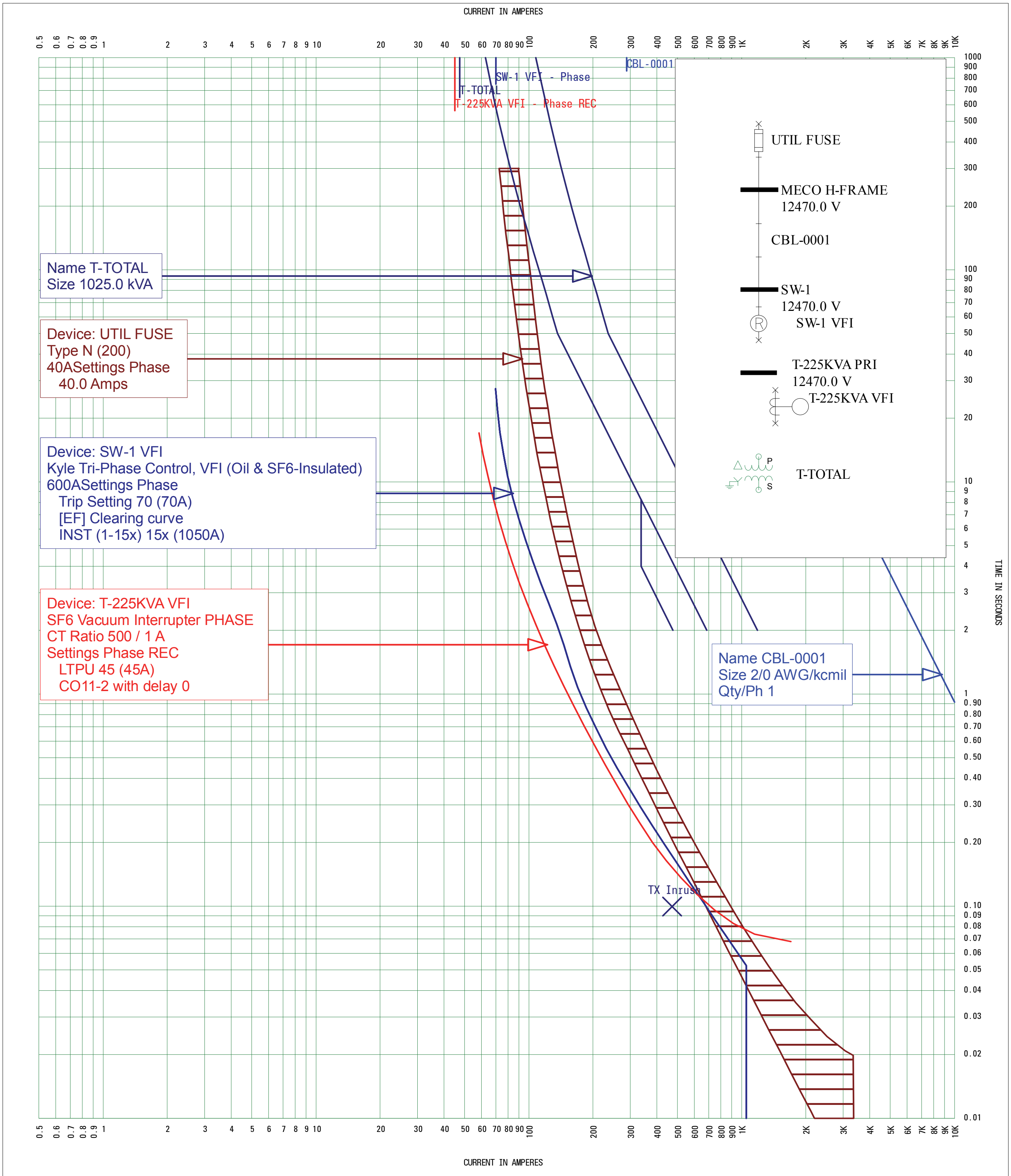
3.6 Time-Current Characteristic Plots

Refer to the following pages for the plotted coordination curves, which graphically indicate the degree of selectivity and protection obtained.

In some cases, a single time-current curve may be applicable to several locations in the system, where each location utilizes substantially similar devices, and serves similar loads.

The following list references the attached time-current curves for this report.

Table 3.1 – TCC Plots Index



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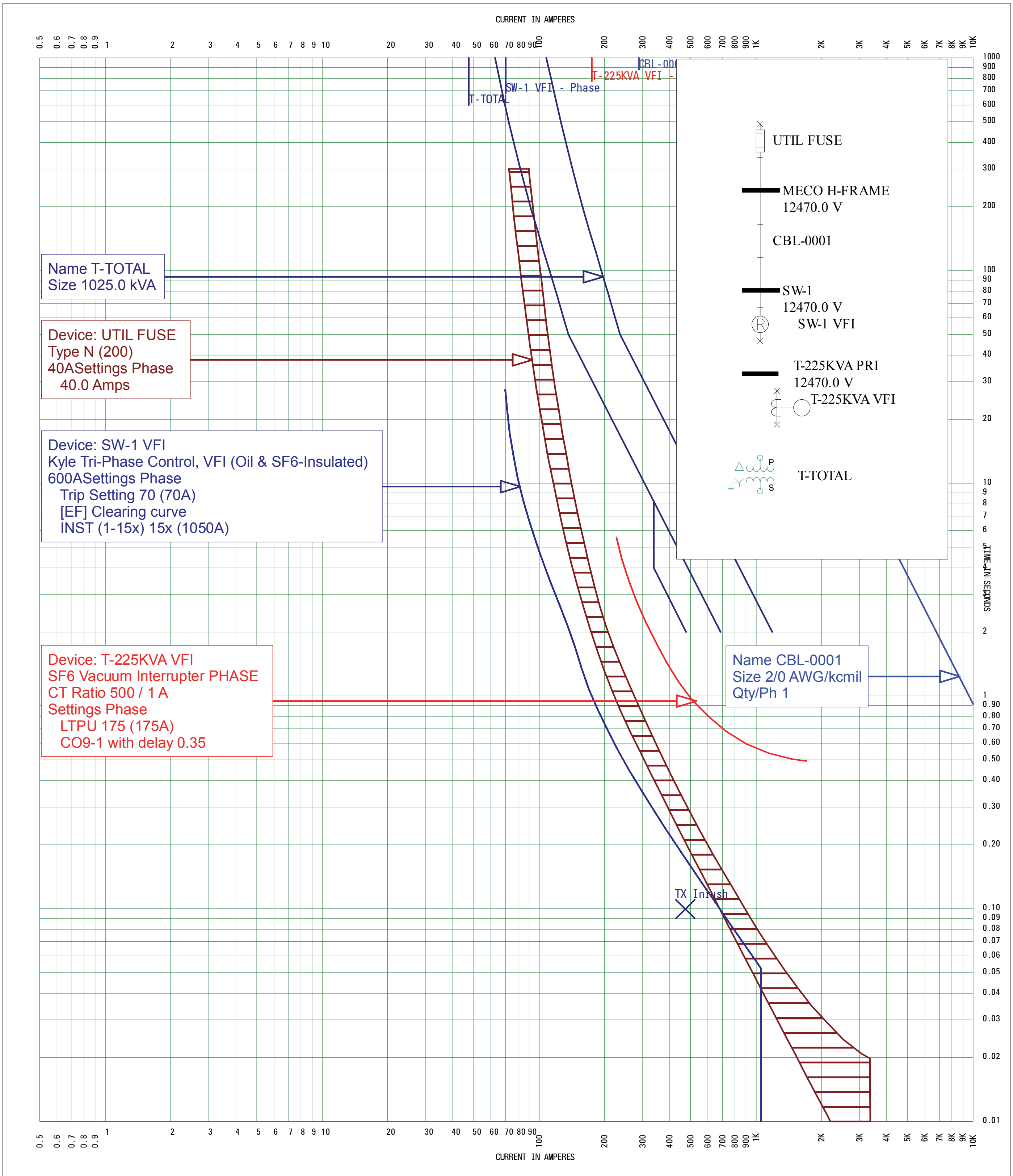

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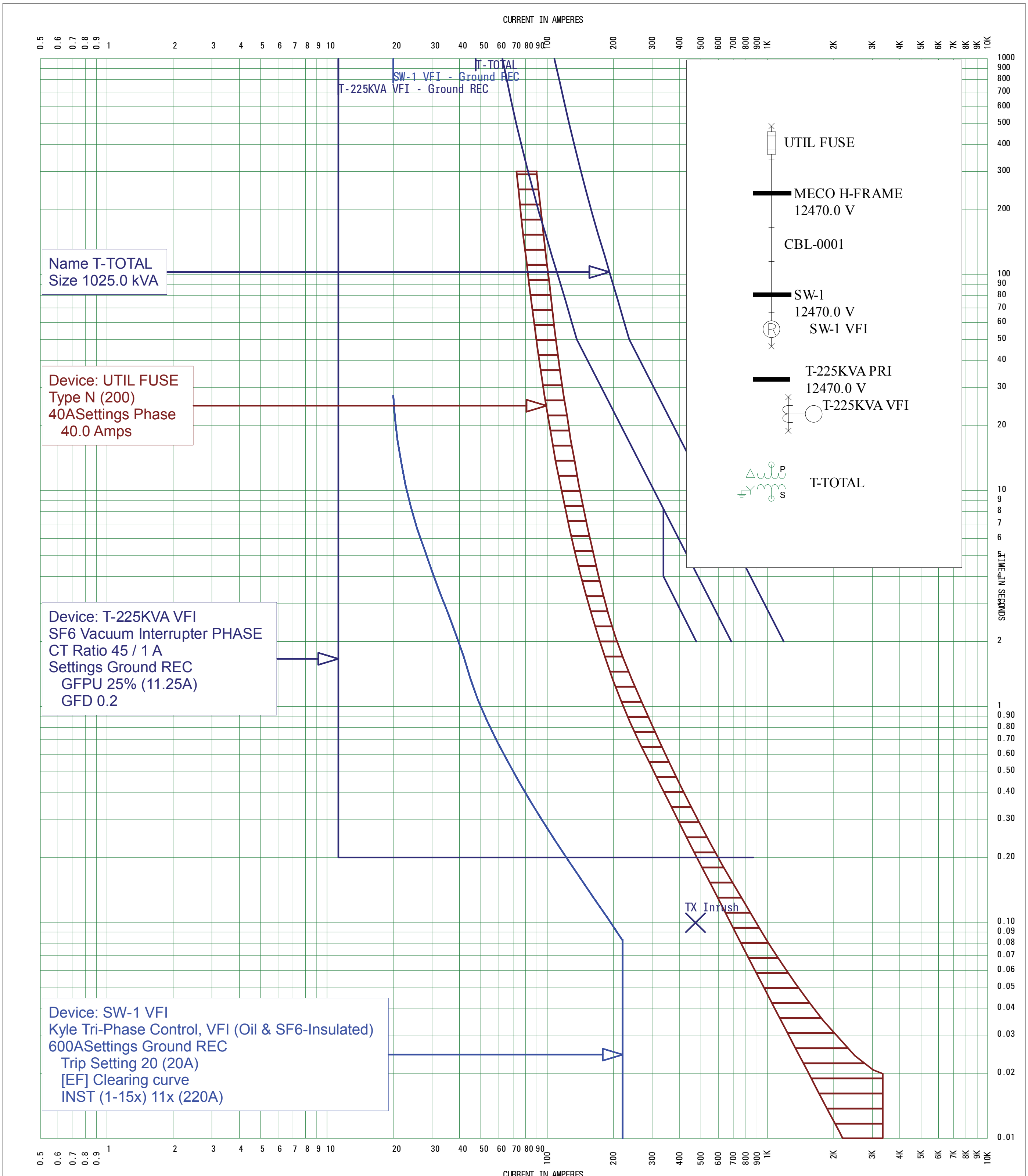

Eaton Electrical Services and Systems	Plot name: 02-UTIL G R Ref. Voltage: 12470V Current Scale: x 1

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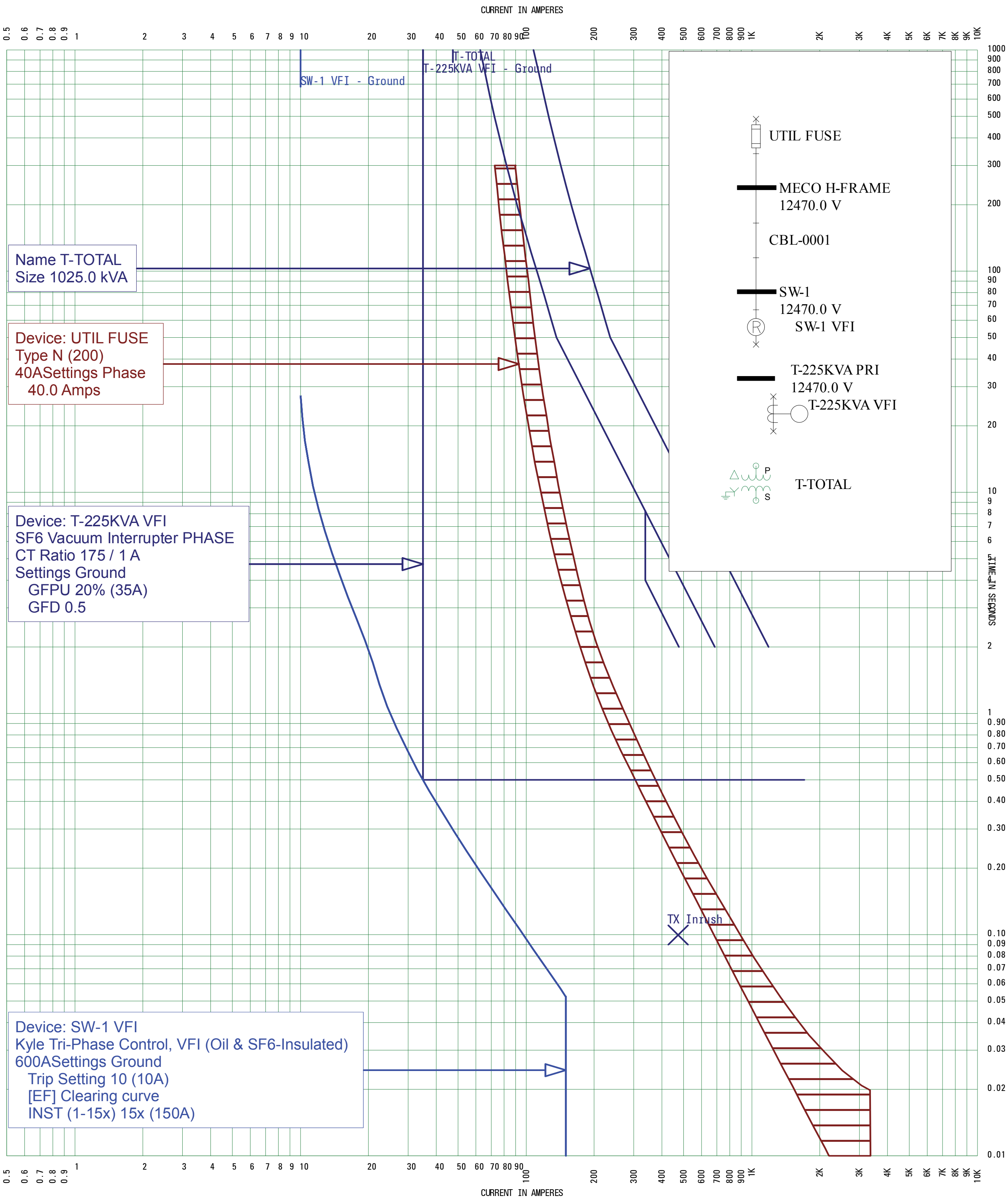
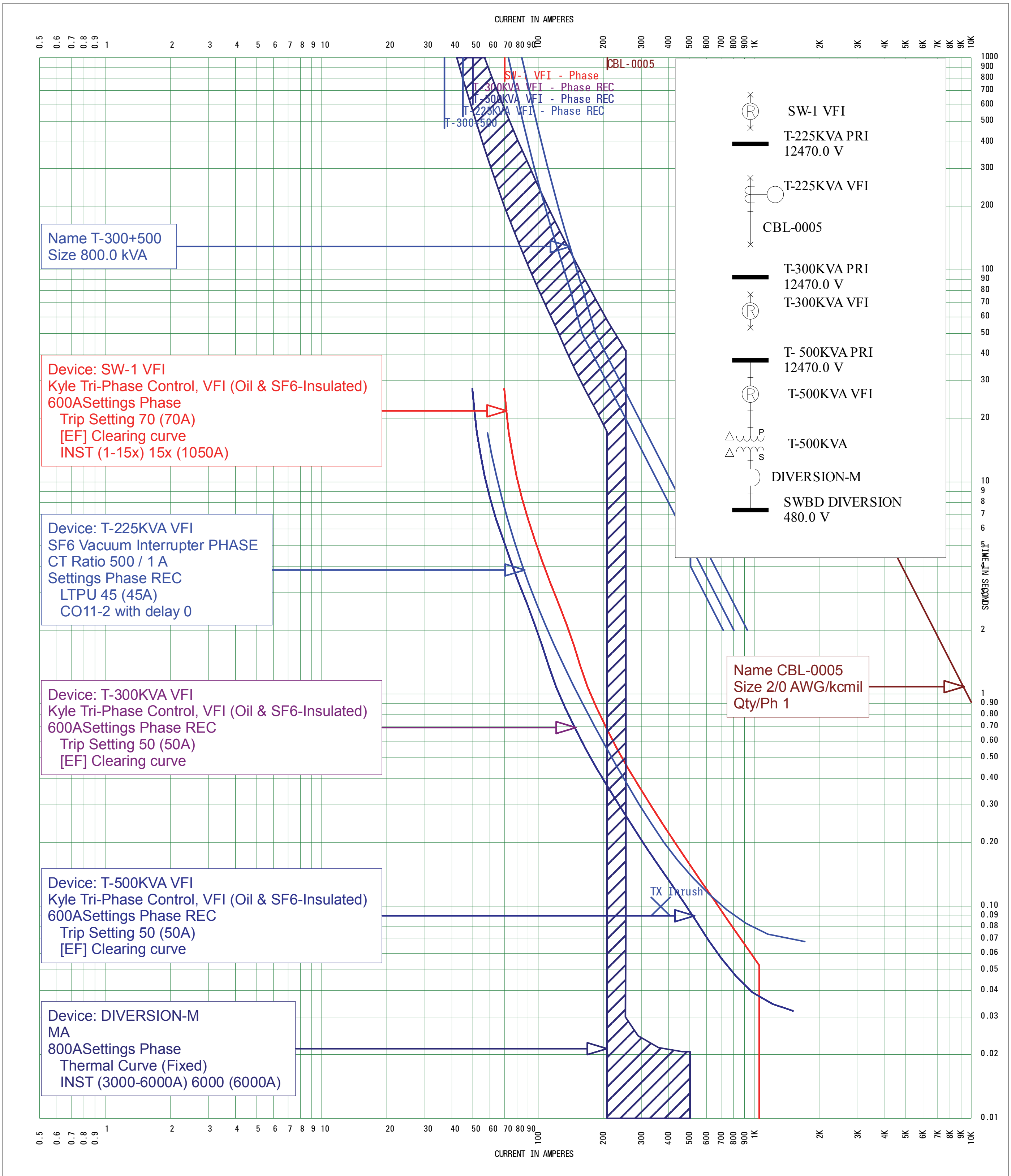
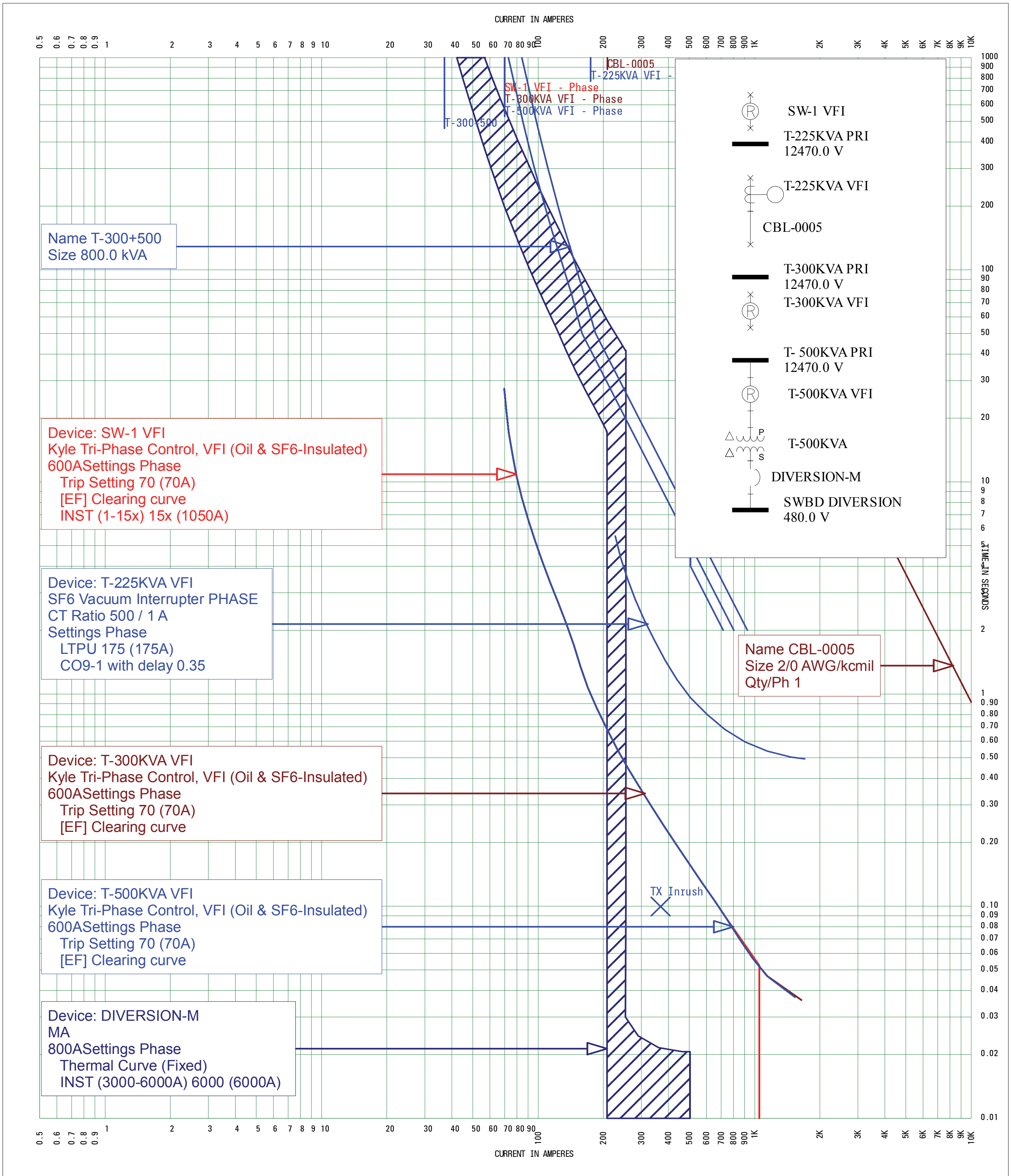


Eaton Electrical Services and Systems

Plot name: 02-UTIL G
Ref. Voltage: 12470V
Current Scale: x 1



Eaton Electrical Services and Systems	Plot name: 03-T300KVA VFI R Ref. Voltage: 12470V Current Scale: x 1



Eaton Electrical Services and Systems

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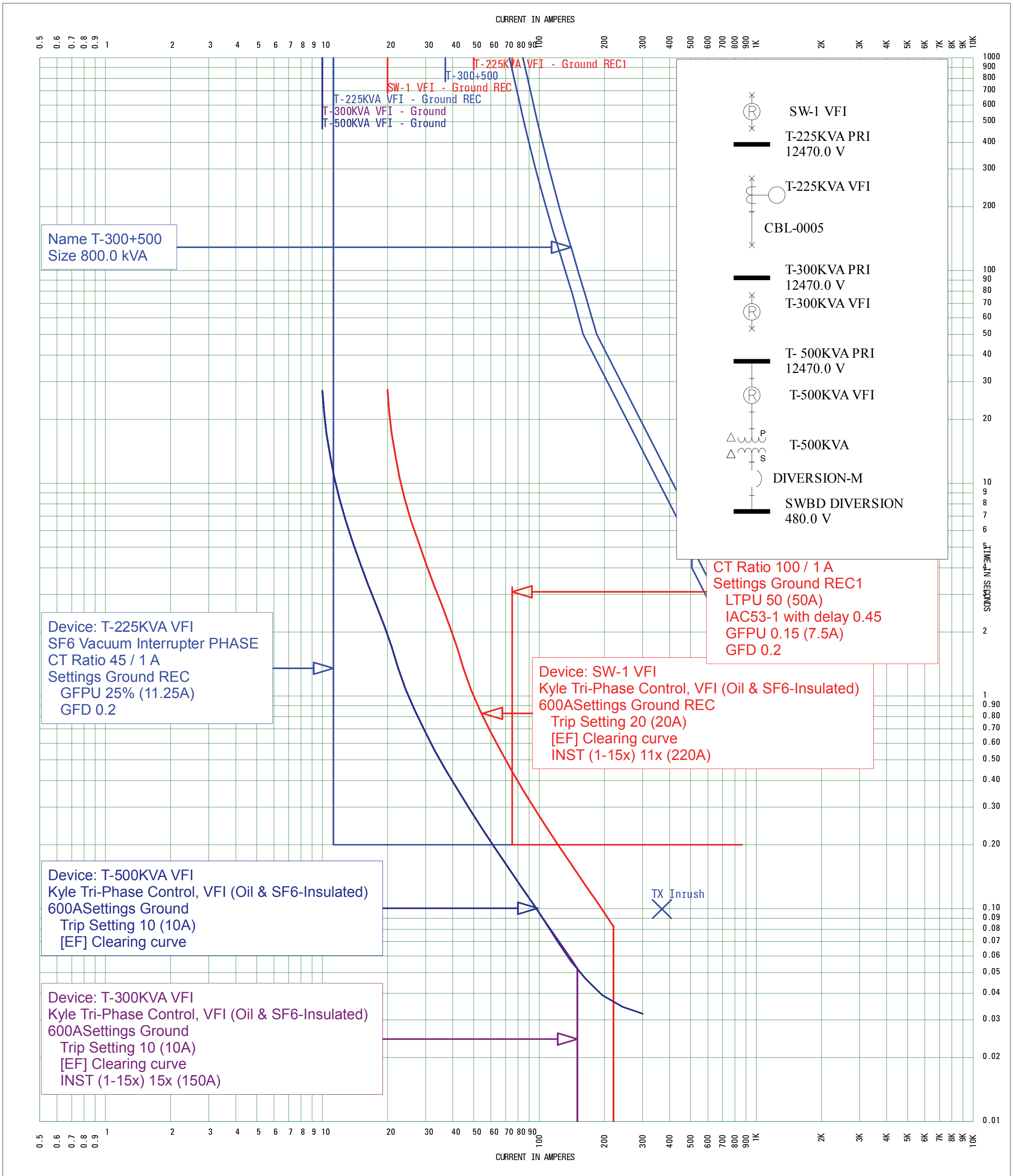

Eaton Electrical Services and Systems

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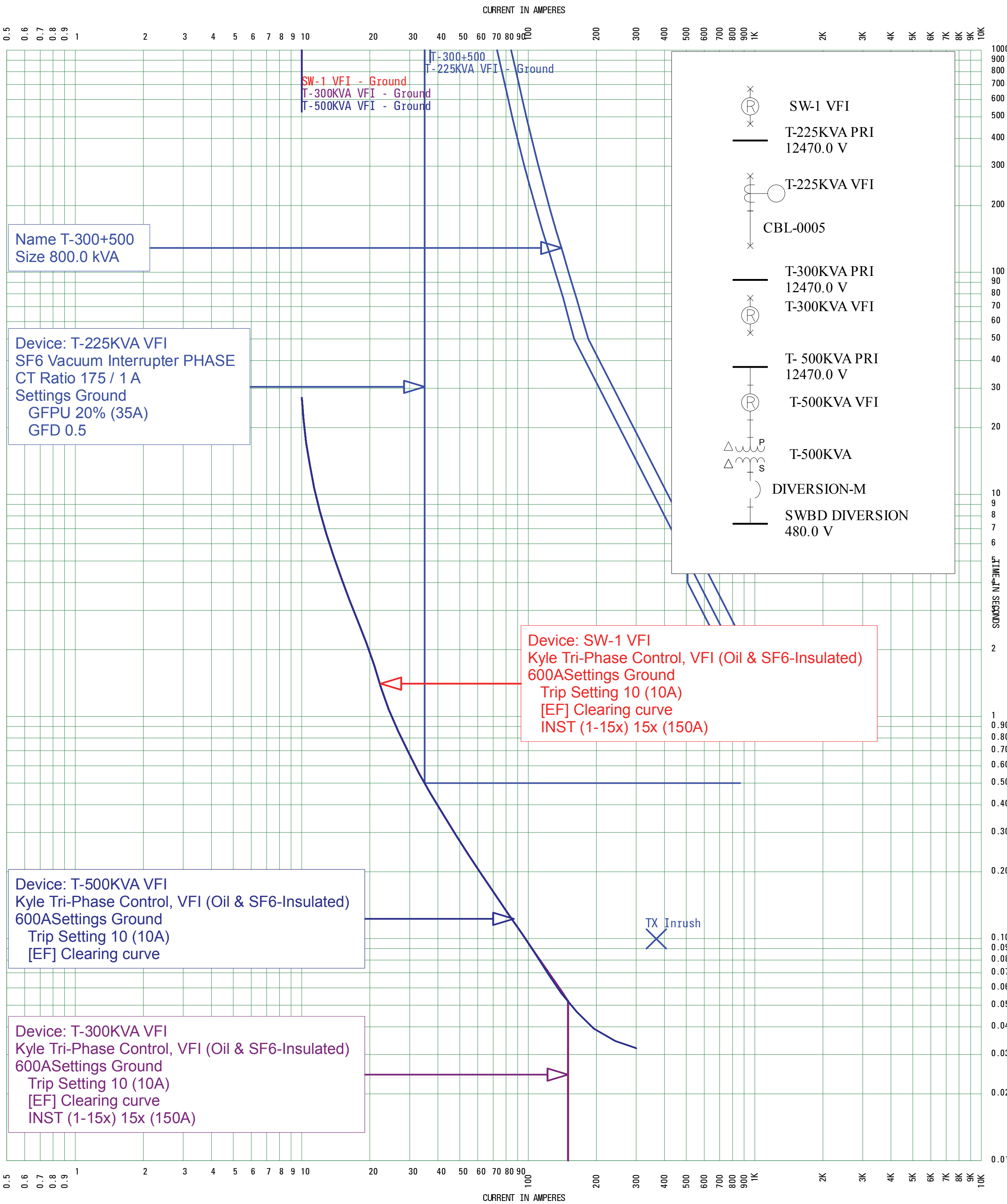

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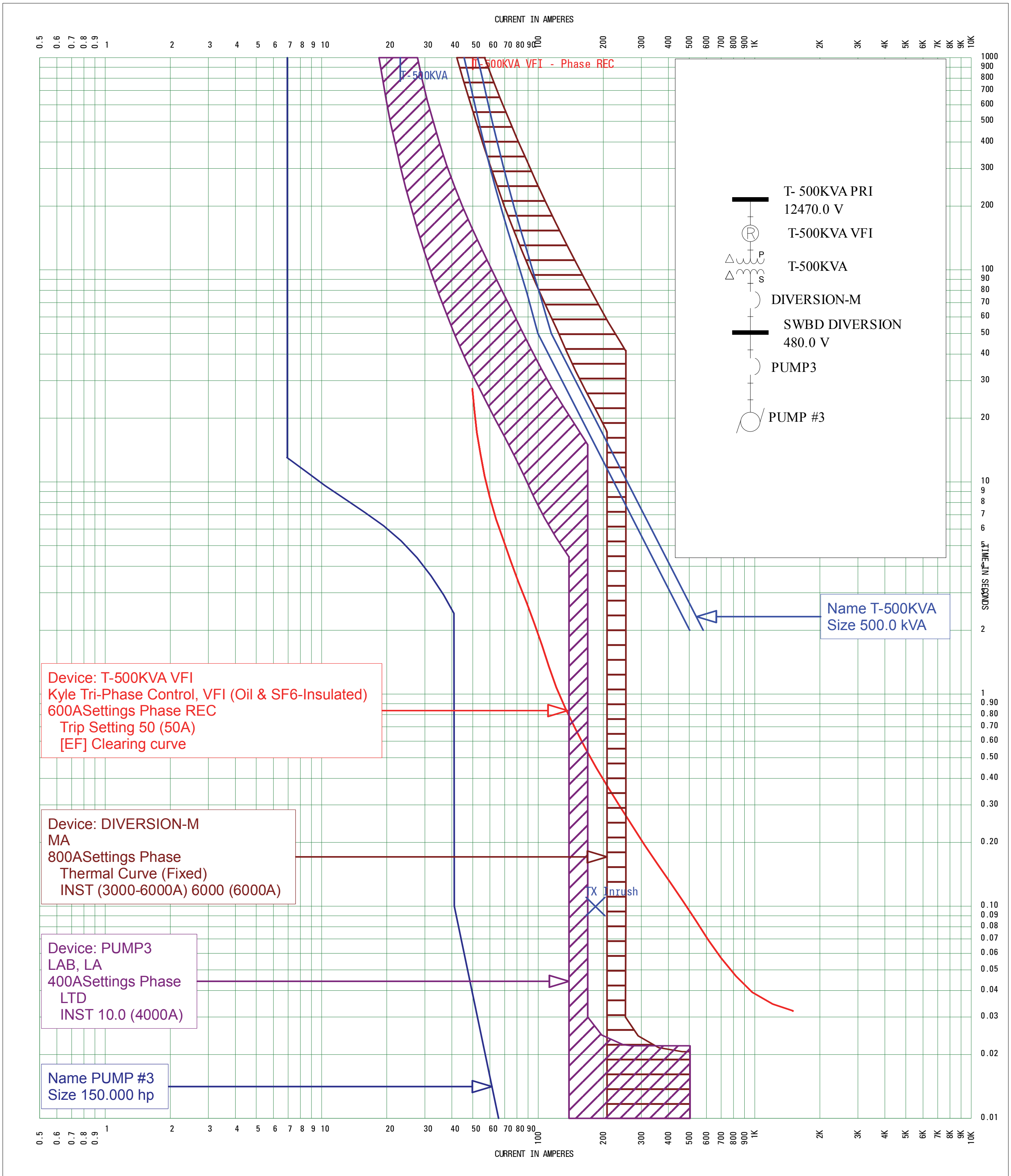

Eaton Electrical Services and Systems

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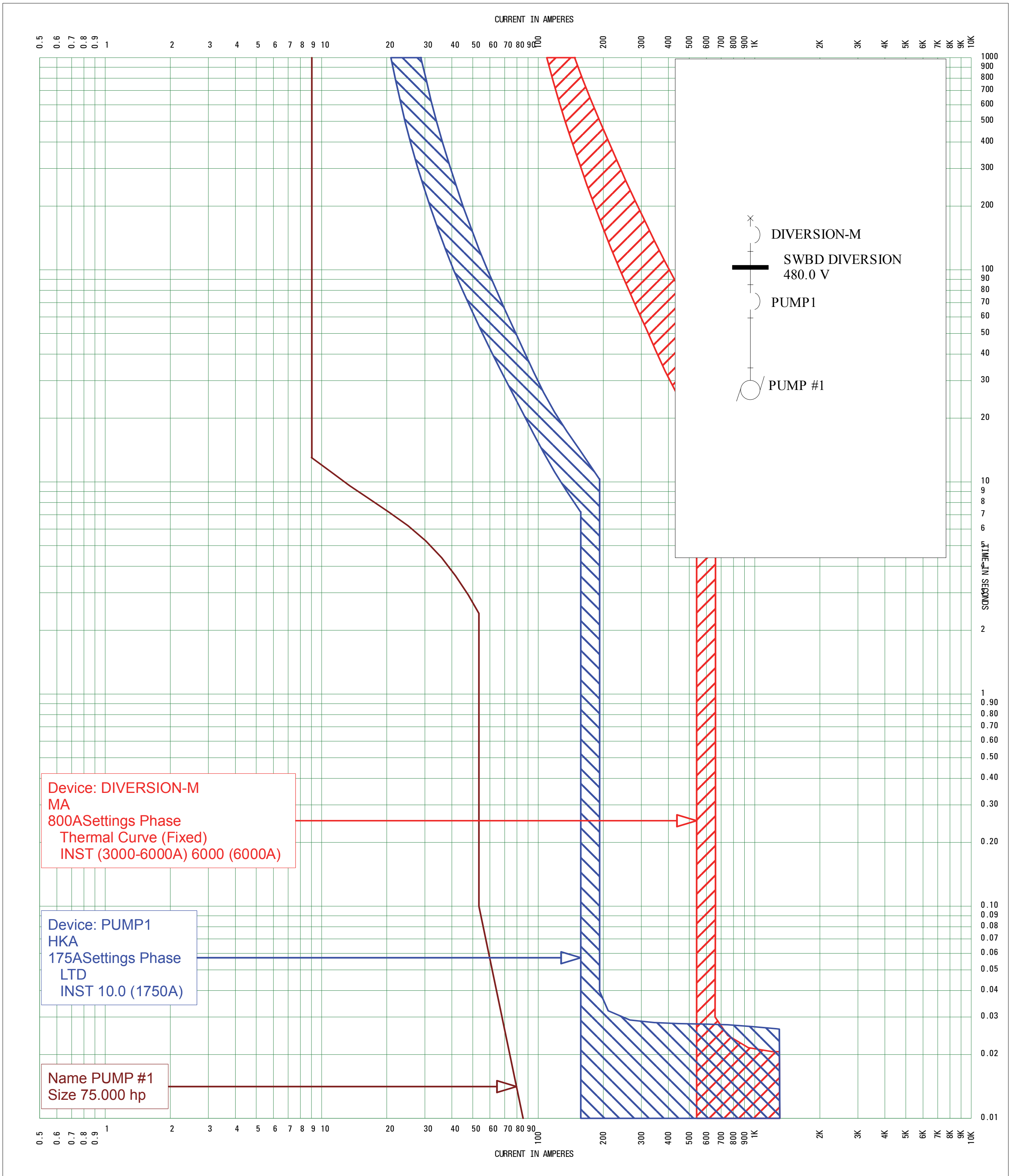
Ref. Voltage: 12470V
Current Scale: x 1



Eaton Electrical Services and Systems	Plot name: 06-PUMP1 Ref. Voltage: 480V Current Scale: x 10

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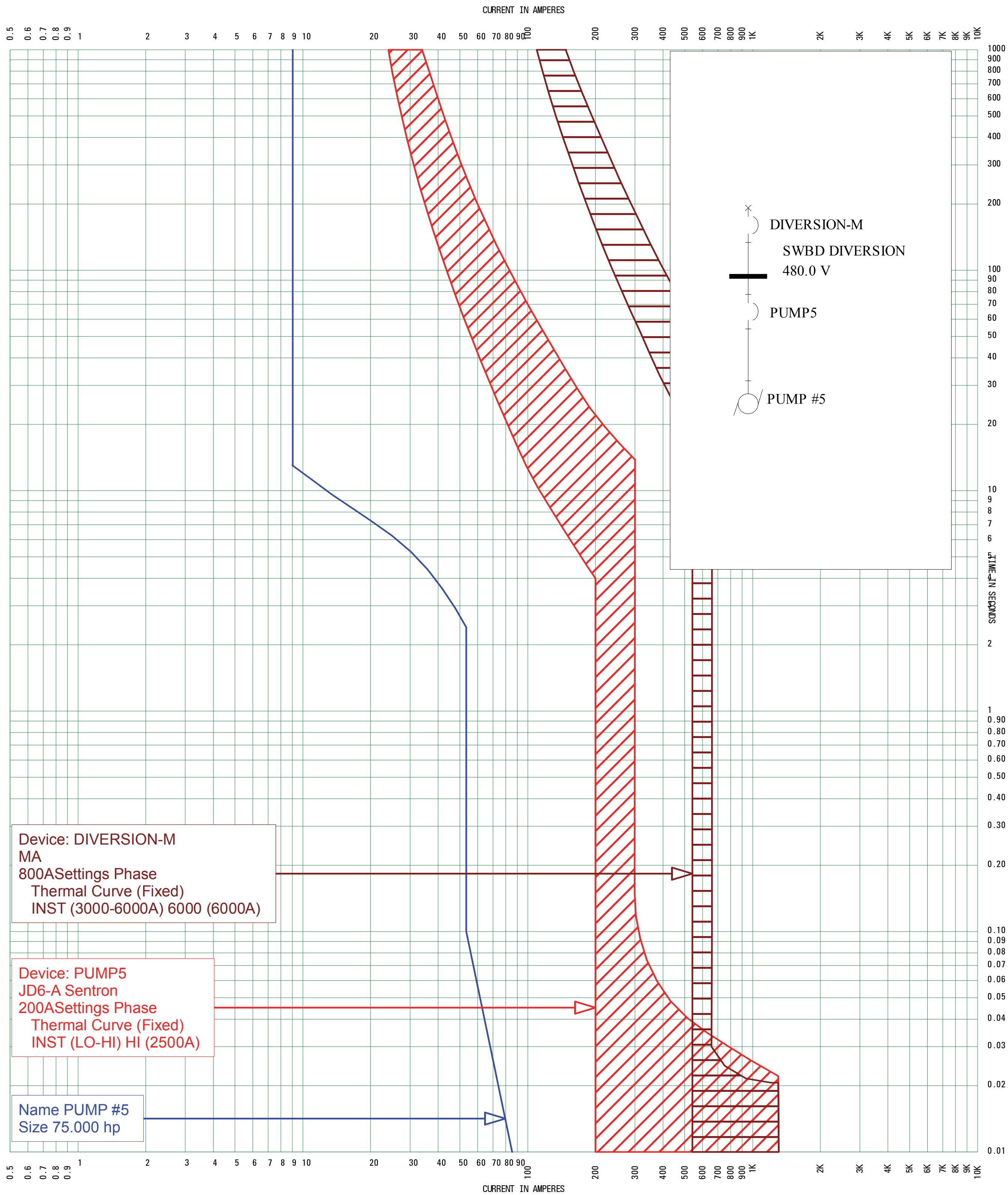
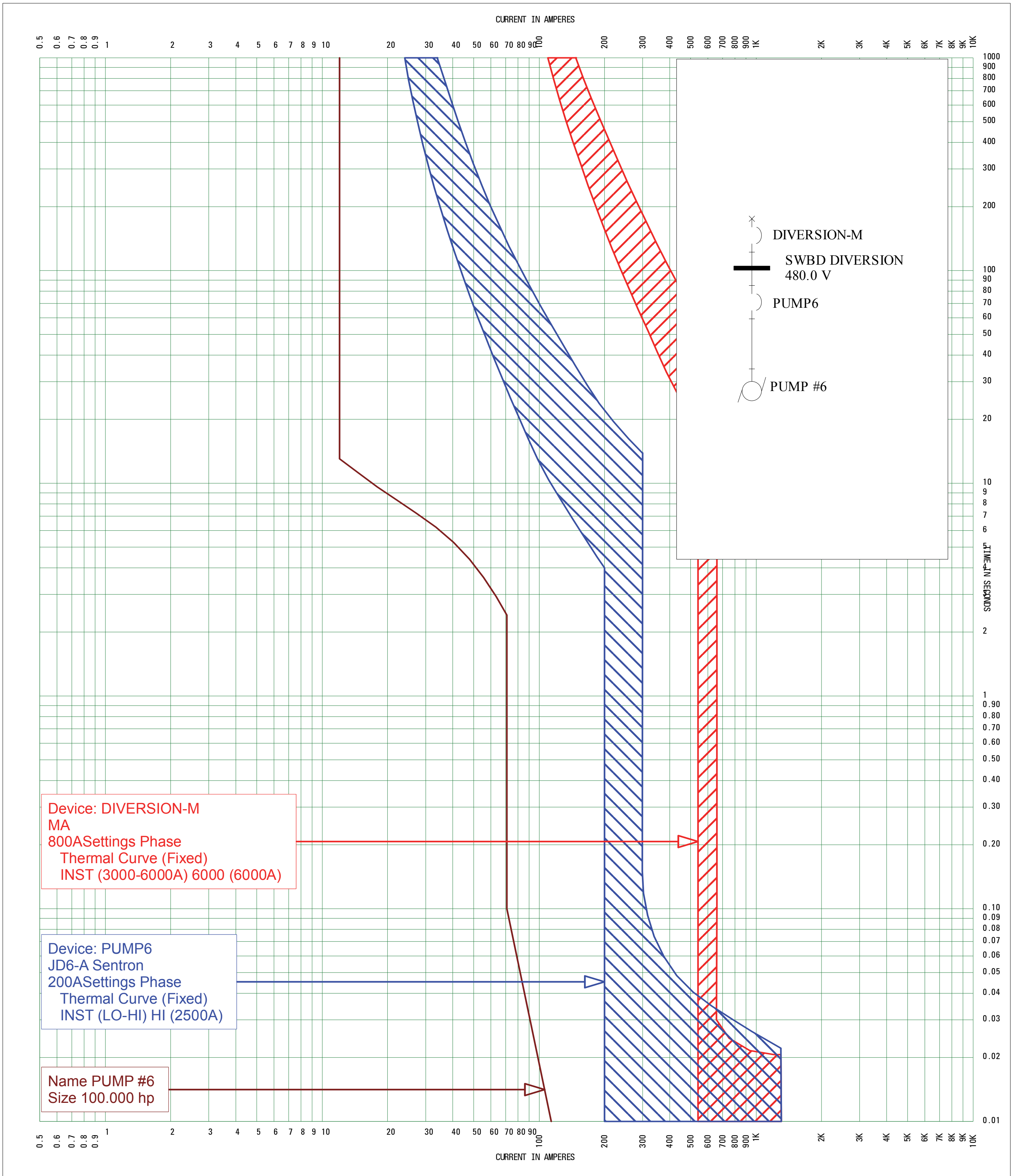
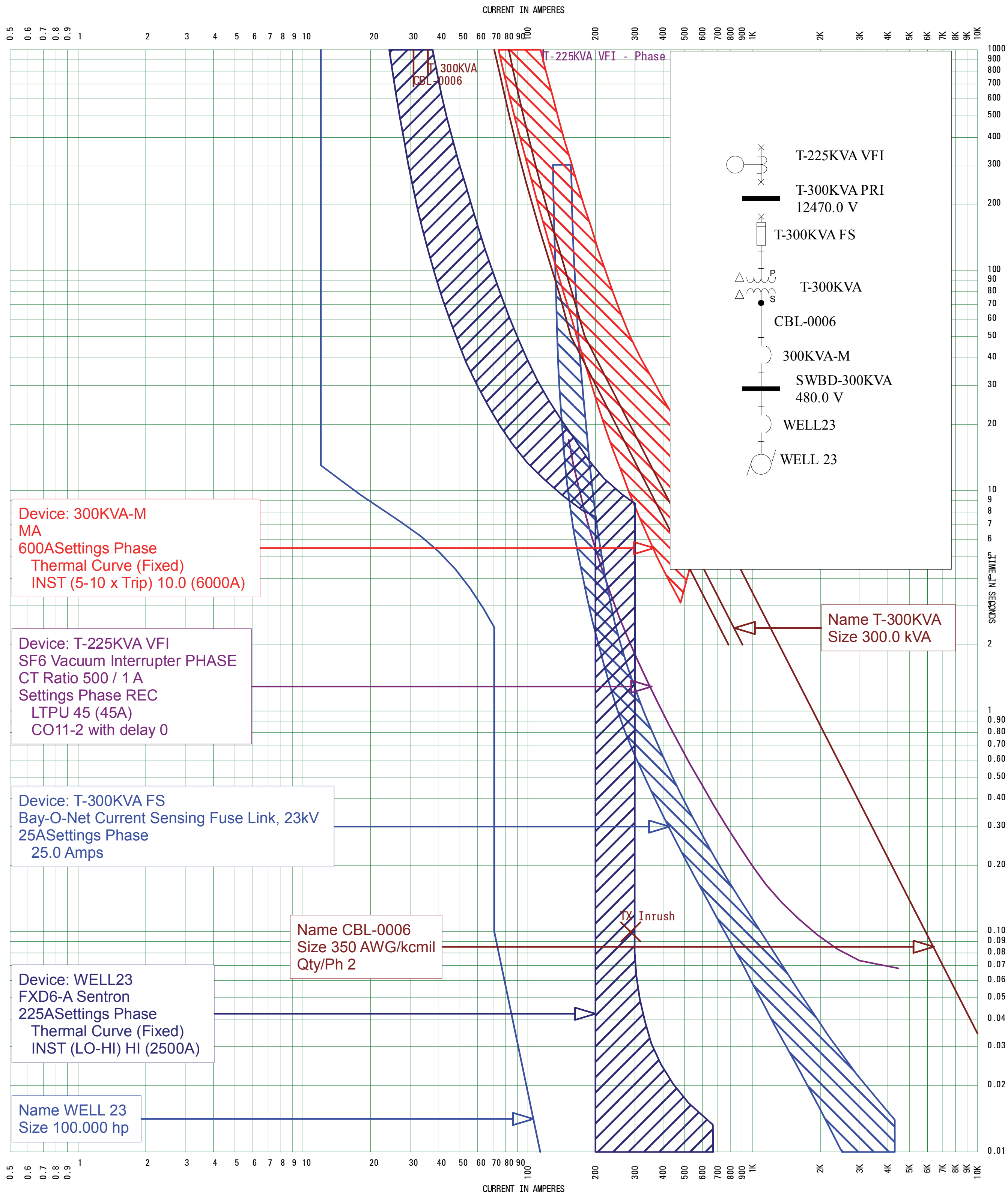


Eaton Electrical Services and Systems	Plot name: 07-PUMP5 Ref. Voltage: 480V Current Scale: x 10



Eaton Electrical Services and Systems	Plot name: 08-PUMP6 Ref. Voltage: 480V Current Scale: x 10



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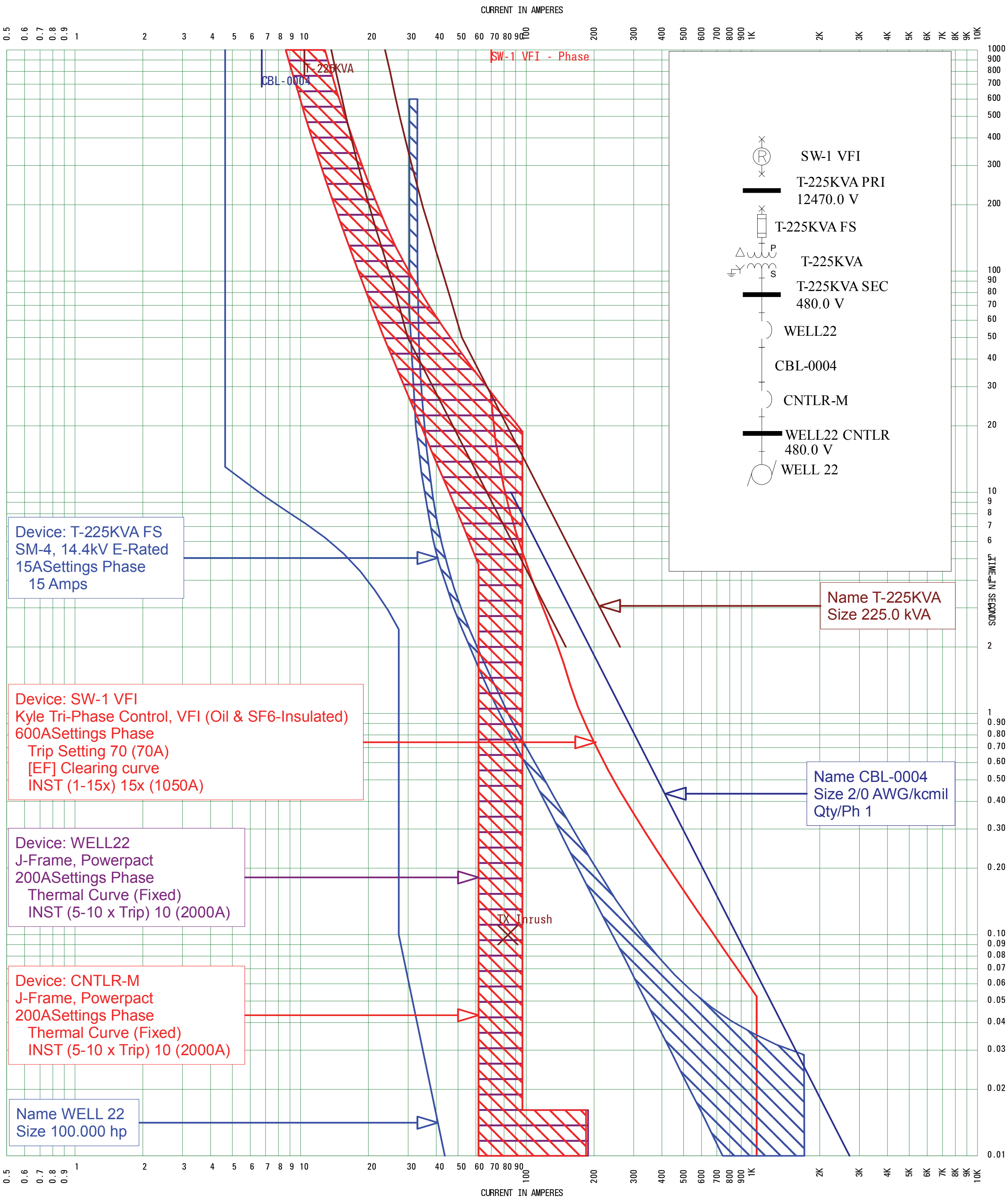
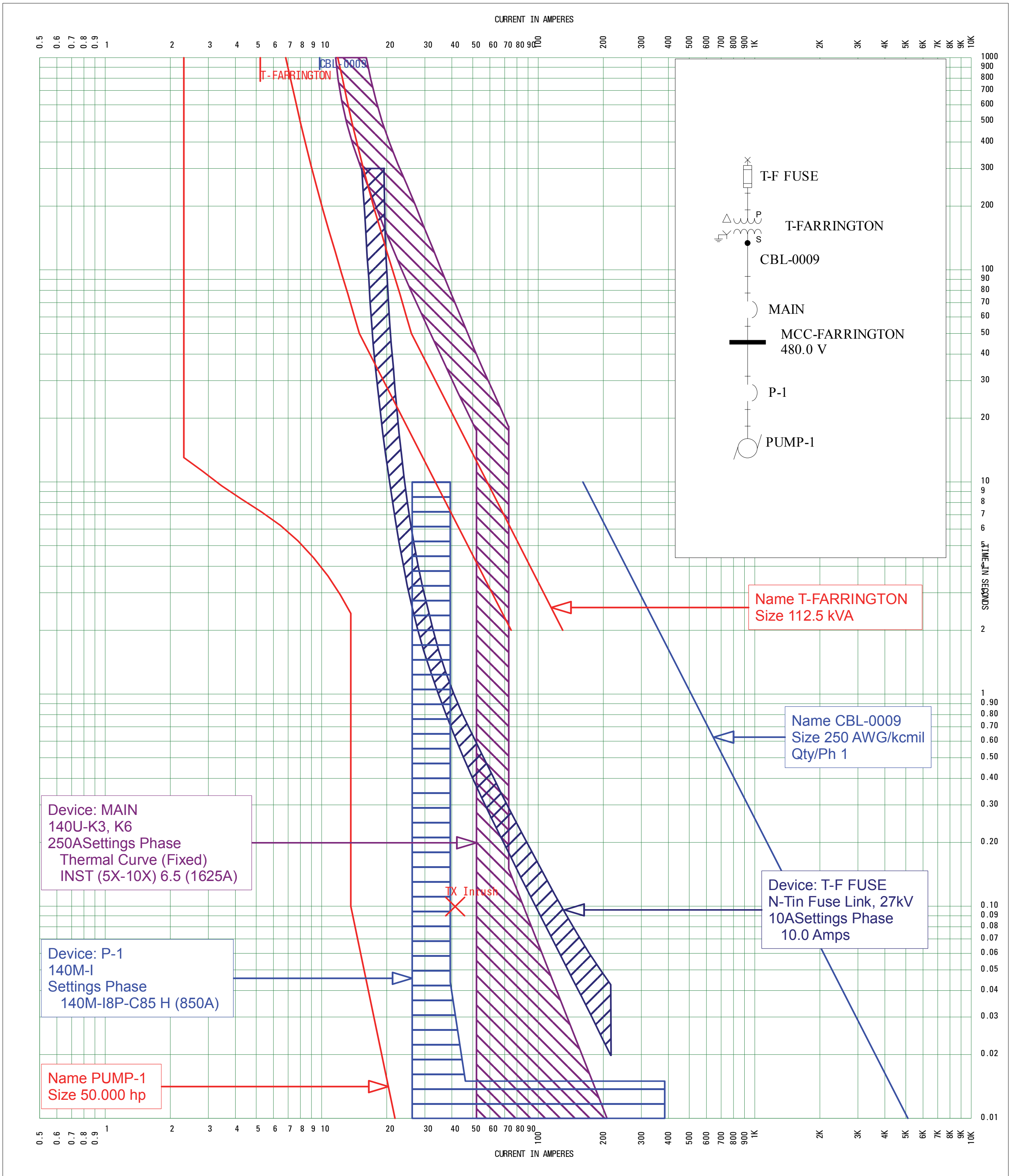


Eaton Electrical Services and Systems

Plot name: 10-WELL22
Ref. Voltage: 12470V
Current Scale: x 1



Eaton Electrical Services and Systems	Plot name: 11-MAIN Ref. Voltage: 12470V Current Scale: x 1

4.0 RECOMMENDED PROTECTIVE DEVICE SETTINGS

The following tables show a comprehensive summary of the recommended settings for the adjustable protective devices. The devices are grouped by system bus name/location. Refer to Appendix D for the system one-line diagram.

Table 4.1 - Recommended Low-Voltage Protective Device Settings

Bus Name	Name/Type	Description	Frame/ Sensor/ Plug	Settings:	TCC#
SWBD-300KVA	300KVA-M	SQUARE D	600A	Thermal Curve (Fixed)	09-300KVA-M
	Thermal Magnetic	MA	600A	INST (5-10 x Trip) 10.0 (6000A)	
		125-1200A			
WELL22 CNTLR	CNTLR-M	SQUARE D	250A	Thermal Curve (Fixed)	WELL22
	Thermal Magnetic	J-Frame, Powerpact	200A	INST (5-10 x Trip) 10 (2000A)	
		150-250A, UL			
SWBD DIVERSION	DIVERSION-M	CUTLER-HAMMER	800A	Thermal Curve (Fixed)	05-DIVERSION-M
	Thermal Magnetic	MA	800A	INST (3000-6000A) 6000 (6000A)	
		125-800A			
MCC-FARRINGTON	MAIN	ALLEN-BRADLEY	400A	Thermal Curve (Fixed)	11-MAIN
	Thermal Magnetic	140U-K3, K6	250A	INST (5X-10X) 6.5 (1625A)	
		100-400A, 3-Pole			
SWBD DIVERSION	PUMP1	WESTINGHOUSE	225A	LTD	06-PUMP1
	Thermal Magnetic	HKA	175A	INST 10.0 (1750A)	
		70-225A			
SWBD DIVERSION	PUMP2	WESTINGHOUSE	225A	LTD	SAME AS PUMP1
	Thermal Magnetic	HKA	175A	INST 10.0 (1750A)	
		70-225A			
SWBD DIVERSION	PUMP3	WESTINGHOUSE	400A	LTD	05-DIVERSION-M
	Thermal Magnetic	LAB, LA	400A	INST 10.0 (4000A)	
		125-600A			
SWBD DIVERSION	PUMP5	SIEMENS	300A	Thermal Curve (Fixed)	07-PUMP5
	Thermal Magnetic	JD6-A Sentron	200A	INST (LO-HI) HI (2500A)	
		200-400A			
SWBD DIVERSION	PUMP6	SIEMENS	300A	Thermal Curve (Fixed)	08-PUMP6
	Thermal Magnetic	JD6-A Sentron	200A	INST (LO-HI) HI (2500A)	
		200-400A			
T-225KVA SEC	WELL22	SQUARE D	250A	Thermal Curve (Fixed)	10-WELL22
	Thermal Magnetic	J-Frame, Powerpact	200A	INST (5-10 x Trip) 10 (2000A)	
		150-250A, UL			
SWBD-300KVA	WELL23	SIEMENS	250A	Thermal Curve (Fixed)	09-300KVA-M
	Thermal Magnetic	FXD6-A Sentron	225A	INST (LO-HI) HI (2500A)	
		70-250A			

Table 4.1 - Recommended Low-Voltage Protective Device Settings

Bus Name	Name/Type	Description	Frame/ Sensor/ Plug	Settings:	TCC#
SWBD-300KVA	WELL24	SIEMENS	250A	Thermal Curve (Fixed)	SAME AS WELL24
	Thermal Magnetic	FXD6-A Sentron	225A	INST (LO-HI) HI (2500A)	
		70-250A			

Table 4.2 - Recommended Medium-Voltage Protective Device Settings

Bus Name	Name/Type	Description	Frame/ Sensor/ Plug	Settings:	TCC#
SW-1	SW-1 VFI	COOPER	600A	Phase	01-UTIL R, 02-UTIL G R
	Recloser	Kyle Tri-Phase Control, VFI (Oil & SF6-Insulated)	600A	Trip Setting 70 (70A)	
		EF, Phase Trip		[EF] Clearing curve	
				INST (1-15x) 15x (1050A)	
				Ground REC	
				Trip Setting 20 (20A)	
				[EF] Clearing curve	
				INST (1-15x) 11x (220A)	
T-300KVA PRI	T-300KVA VFI	COOPER	600A	Phase REC	03-T300KVA VFI R, 04-T300KVA VFI G R
	Recloser	Kyle Tri-Phase Control, VFI (Oil & SF6-Insulated)	600A	Trip Setting 50 (50A)	
		EF, Phase Trip		[EF] Clearing curve	
T- 500KVA PRI	T-500KVA VFI	COOPER	600A	Phase REC	03-T300KVA VFI R, 04-T300KVA VFI G R
	Recloser	Kyle Tri-Phase Control, VFI (Oil & SF6-Insulated)	600A	Trip Setting 50 (50A)	
		EF, Phase Trip		[EF] Clearing curve	
				Ground	
				Trip Setting 10 (10A)	
				[EF] Clearing curve	
T-225KVA PRI	T-225KVA VFI	G&W Elect	500 / 1	Phase REC	03-T300KVA VFI R, 04-T300KVA VFI G R
	Electronic	SF6 Vacuum Interrupter PHASE		LTPU 45 (45A)	
		Type 2 Module		CO11-2 with delay 0	
				Ground REC	
				GFPU 25% (11.25A)	
				GFD 0.2	

5.0 ARC FLASH HAZARD ANALYSIS

This section of the report contains the interpretation for the arc flash hazard analysis. The calculations made in this arc flash hazard analysis conform to NFPA 70E, and are based on the information provided by the customer. Actual heat and radiation exposure may be more or less than reflected in the analysis.

Only qualified electricians who are familiar with the installation and maintenance of electrical distribution equipment should perform work associated with such products. All recommendations of the manufacturer, warnings and cautions relating to the safety of personnel and equipment should be followed. All applicable health and safety laws, codes, standards, and procedures should be adhered to. All equipment should be de-energized prior to any maintenance or service. OSHA 1910.333 requirements should be adhered to. All guidelines of NFPA 70E-2012 should be followed, and in particular appropriate personal protective equipment must be provided and worn.

Eaton Corporation will not be responsible for the misuse or misapplication of the information contained in this analysis. Those providing service for electrical equipment should contact an Eaton Electrical Services and Systems representative, or other qualified individual, if any questions arise.

5.1 Introduction

NFPA 70E-2012, Article 110.3(F) requires that an employer developed electrical safety program includes a hazard identification and risk evaluation procedure. This procedure is meant to be used before performing work on or near any equipment at or above 50 volts or any time work is being performed where an electrical hazard exists. This analysis presents only the results of an incident energy evaluation conducted in accordance with 130.5(B). The risk depends on a number of factors. These include the nature of the task being performed and the condition of the equipment. Selection of personal protective equipment (PPE) must be made based on the incident energy level that is presented in this report and a risk assessment to be made by the qualified person. NFPA 70E-2012, Article 130.7(A) requires that employees use and employers provide proper PPE for the tasks being performed. NFPA 70E-2012, Table H.3(b) provides guidance for the selection of PPE based on calculated incident energy exposure.

NFPA 70E-2012 and IEEE Std 1584-2002 provide equations and methods to accurately calculate the arc flash boundary and incident energy at specific locations within a facility's electrical system. Any location where work may be performed on or near energized electrical conductors and circuit parts is subject to the arc flash standards. PPE used to guard against arc flash hazard should be considered the last line of defense. It is also important to note that the use of PPE is not intended to prevent all injuries from an arc flash. The goal of determining PPE levels using the arc flash hazard approach is to identify the level of protection required to limit the injury to the onset of a second degree burn in the event of an arc flash while avoiding the use of more protection than is needed so as to minimize hazards of heat stress, reduced visibility and limited body movement.

Although the arc flash calculation procedure is based upon NFPA 70E and IEEE Std 1584-2002 equations and methods, it is a relatively new approach to determining the degree of required PPE. The calculations are derived from theory and research involving arc current incident energy measurements conducted under a specific set of controlled test conditions. Therefore, calculation results may be more severe or less severe than the hazard presented by an actual arc flash exposure. Also, the arc flash hazard calculations do not take into account hazards associated with the splattering of molten metal, explosively propelled pieces of equipment and air pressure shock waves.

The results of this arc flash hazard analysis are not intended to imply that personnel be permitted to work on exposed energized equipment or circuits. OSHA 1910.333 restricts the situations in which work is to be performed near or on energized equipment or circuits by stating, "Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations."

Even if work is not being performed directly on energized equipment, it is important that the proper PPE be used during some load interruption actions, during visual verification of the state of disconnecting devices, and during lockout/tagout procedures.

5.2 Study Procedure

In accordance with NFPA 70E and IEEE Std 1584-2002, SKM Systems Analysis software provides the calculation of these values. The equations used in these calculations are based on actual test values. These tests measured the calories per square centimeter (cal/cm^2) radiating from a simulated arcing fault. The measurements were performed at a theorized working distance of 18 inches for typical low-voltage equipment (MCC, panelboards, switches etc), 24 inches for low-voltage switchboards, and 36 inches for medium voltage switchgears.

The intent of NFPA 70E and IEEE Std 1584-2002 guidelines is to establish standard calculations to determine an approach boundary that will prevent the onset of a second-degree burn to the face and the torso of the worker. An incident energy of 1.2 cal/cm^2 represents the onset of a second-degree burn.

Before the arc flash equations can be applied, a comprehensive short-circuit and protective device coordination study must be completed to include all locations where work may be performed on or near energized components; e.g. motor control centers and power distribution panels. Since the short-circuit current must be calculated at every pertinent location and the clearing time of each location's upstream protective device is required, the arc flash circuit model is more detailed and extends deeper into the facility electrical distribution system than is typical of a basic short-circuit and protective device coordination study. Accurate fault currents and device clearing times are extremely important in deriving reliable results. A conservative (high) fault current value could yield a faster clearing time of a protective device, depending upon its curve shape, and the calculated incident energy may actually be less than the incident energy calculated for a lower magnitude of fault current and a longer clearing time.

1. <u>Arc Flash Scenarios</u>

Since the greatest arc flash hazards may not result from the highest fault current, multiple scenarios must be analyzed and compared. The following modes of operation have been evaluated in order to determine the worst-case incident energy at each location in the system. It is important to determine the available short-circuit current for modes of operation that provide both the maximum and minimum available short-circuit currents.

- Arc Flash Scenario 1 – *Normal Source Motor On/Off*
- Arc Flash Scenario 2 – *Minimum Fault Normal Source Motor On/Off*

2. <u>Assumptions</u>

The following assumptions were used in performing the arc flash analysis, and ensure conservative, worst-case results:

- The minimum utility fault current is assumed to be 80% of the available fault current at the incoming utility contribution. Minimum fault current is 2,640A based on 80% of 3,300A for the MECO H-FRAME and 11,840A based on 80% of 14,800A for the MCC-FARRIGTON.

The analysis required energy and boundary calculations for approximately nine (9) locations.

5.3 Arc Flash Hazard Analysis Results

The incident energy associated with an arc flash is dependent upon the following parameters:

- The maximum "bolted fault" three-phase short-circuit current available at the equipment and the minimum fault level at which the arc will self-sustain.
- The total protective device clearing time (upstream of the prospective arc location) at the maximum short-circuit current and the minimum fault level at which the arc will self-sustain.
- The distance of the worker from the prospective arc for the task to be performed.

The arc flash hazard analysis results shown in Table 5.1 are based on a protective device clearing time that is capped at 2 seconds. This is based on IEEE Std 1584-2002 which states in Annex B, Instructions and Examples; *"If the time is longer than two seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible, and two seconds is a reasonable maximum time for calculations. A person in a bucket truck or a person who has crawled into equipment will need more time to move away."*

Two calculations are typically provided for labels on locations where there is adequate separation between the line side terminals of the main protective device, and the work location. The "Load Side" calculation provides the incident energy based on the main protective device clearing in the event of an arc flash incident. If the work location or task is such that the main breaker may not trip in the event of an arc flash incident, then the "Line Side" calculation for incident energy should be observed. This could occur if the main breaker is being racked-out, and a fault occurred on the line terminals. For this case, the next upstream device is the one that must clear the fault.

One should always remember that the terms "Line Side" and "Load Side" are always in reference to the main protective device (see example below).

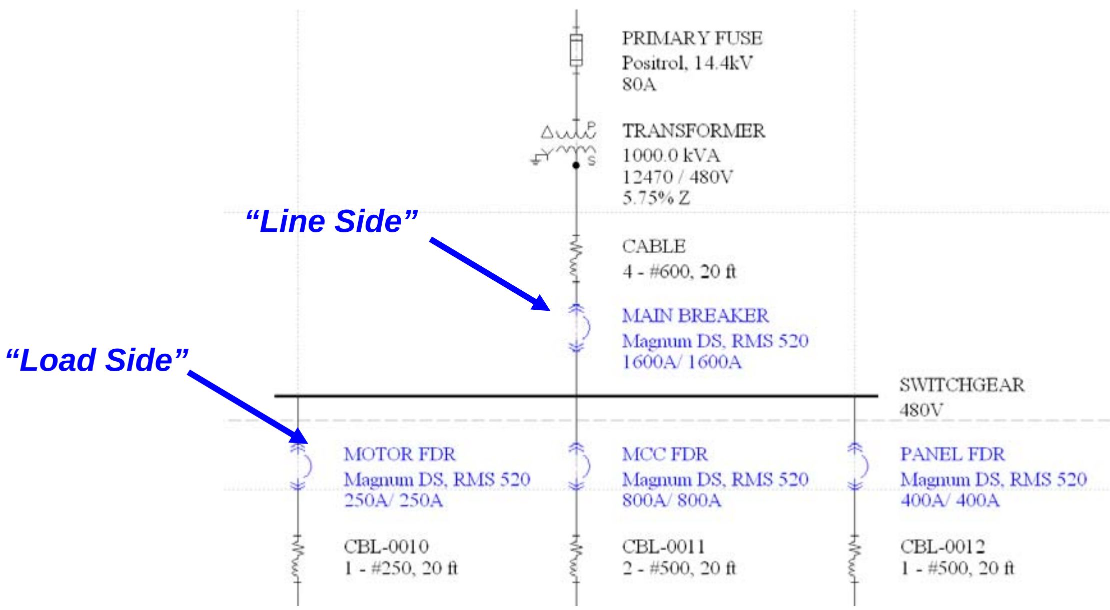


Figure 1: Line Side vs. Load Side

The fault current cannot easily be reduced nor can the working distance be easily increased to lessen the incident energy. In many locations the protective device setting can be adjusted or the trip unit upgraded to decrease the device interrupting time that will in turn decrease the incident energy. For a critical electrical distribution system, such as for Molokai Irrigation System, it is essential that the system reliability not be compromised. Settings for protective devices cannot be adjusted if the chance of nuisance trips within critical circuits is introduced. *Each location where the hazard is determined to* *be unacceptable by “Molokai Irrigation System” must be individually evaluated to determine the most effective means of reducing the incident energy while maintaining the highest degree of reliability.*

All of the adjustable protective devices listed in Section 4 must be set per the recommended settings of this study to achieve the incident energy levels shown in Table 5.1.

5.4 Arc Flash Summary Table Heading Descriptions

Table 5.1 show results of the SKM PowerTools arc flash hazard analysis. The following column headings describe the results.

Column #1 - Bus Name: The names in this column correlate to the names implemented in the software system model (reference the one-lines included in Appendix D) These locations correspond to plant locations such as main switchboards, panelboards, enclosed breakers, etc.

Column #2 - Protective Device Name: This column lists the name of the device primarily responsible for clearing a potential fault at the associated bus. Again, these device names correlate to the system model.

Column #3 - Bus Voltage (kV): The values in this column show the nominal voltage of the bus location noted in Column #1.

Column #4 - Bus Bolted Fault (kA): This column shows the bolted fault current available for the bus location referenced in Column #1. This current value corresponds to the system operating conditions that will result in the worst-case calculated value for incident energy. (See Column # 14.)

Column #5 - Prot Dev Bolted Fault (kA): This column displays the portion of calculated bolted fault currents (See Column #4) that is contributed through the protective device referenced in Column #2.

Column #6 - Prot Dev Arcing Fault (kA): This column displays the portion of calculated arcing fault currents that is contributed through the protective device referenced in Column #2. These values demonstrate a reduction in available fault current due to the arc resistance.

Column #7 - Trip/Delay Time (sec): This column displays the length of time required by the protective device (See Column #2) to trip in the presence of the arcing fault current calculated in Column #6. For low voltage breakers and fuses, this time represents the total clearing time of the device.

Column #8 - Breaker Opening Time (sec): For circuit breakers tripped by a relay, this column shows the opening time of the breaker. This time is added to the Trip time (See Column #7) to determine the total clearing time used in the calculation of incident energy. (See Column #14.)

Column #9 - Gnd: This column indicates whether the fault location includes a path to ground. Systems with high-resistance or low-resistance grounds are assumed to be ungrounded in the arc flash calculations.

Column #10 - Equip Type: This column indicates whether the equipment is Switchgear, Panel, Cable or Open Air. The equipment type provides a default Gap value, and a distance exponent used in the IEEE incident energy equations.

Column #11 – Gap (mm): This column displays the spacing between bus bars or conductors at the arc location.

Column #12 - Arc Flash Boundary (in): This column displays the distance within which a person must be clothed in the appropriate PPE (Personal Protection Equipment.) (See Column #14.)

Column #13 - Working Distance (in): This distance indicates the typical working distance associated with the system location referenced in Column #1.

Column #14 - Incident Energy (cal/cm^2): Based on the arcing fault current, the total clearing time of the protective device, the bus bar gap, the grounding method, and the typical working distance, the column displays the results of the arc flash calculations at the reference location. This energy level directly corresponds to the appropriate PPE required for each location. NFPA 70E-2012, Table H.3(b) provides guidance for the selection of PPE based on calculated incident energy exposure.

5.5 Arc Flash Hazard Analysis Recommendations

1) All of the adjustable protective devices listed in Section 4 must be set per the recommended settings to achieve the incident energy levels listed in Table 5.1.
2) Each location where the arc flash hazard is unacceptable to "Molokai Irrigation" should be individually evaluated to determine the most effective means of reducing the incident energy while maintaining the highest degree of reliability.

Table 5.1 – Arc Flash Analysis Summary Table

Bus Name	Protective Device Name	Bus Voltage (kV)	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Gnd	Equip Type	Gap (mm)	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm^2)
MCC-FARRINGTON	T-F FUSE	0.48	11.14	10.44	5.73	0.042	0.000	Yes	PNL	25	14	18	0.8
SW-1	UTIL FUSE	12.47	3.30	3.30	3.26	0.02	0.000	Yes	SWG	153	2	36	0.1
SWBD DIVERSION	T-300KVA VFI	0.48	13.39	10.05	5.37	0.379	0.083	No	PNL	25	70	18	11.1
SWBD-300KVA	T-300KVA FS	0.48	6.86	5.45	3.21	1.123	0.000	No	PNL	25	84	18	14.8
T- 500KVA PRI	SW-1 VFI	12.47	1.64	1.54	1.54	0.001	0.083	Yes	SWG	153	4	36	0.2
T-225KVA PRI	UTIL FUSE	12.47	1.80	1.65	1.65	0.04	0.000	Yes	SWG	153	2	36	0.1
T-225KVA SEC	T-225KVA FS	0.48	4.97	4.26	2.63	0.692	0.000	Yes	PNL	25	46	18	5.6
T-300KVA PRI	UTIL FUSE	12.47	1.74	1.60	1.60	0.041	0.000	Yes	SWG	153	2	36	0.1
WELL22 CNTLR	WELL22	0.48	4.92	4.21	3.06	0.016	0.000	Yes	PNL	25	6	18	0.2

A. APPENDIX A – SHORT-CIRCUIT INPUT REPORT

Input Report Interpretation

Input Data Tables are provided on the following pages. The following is a guide for interpreting the input data.

1. Generation Contribution Data

- Utility contribution data includes the available fault current in MVA and amps, per unit impedance on a 100 MVA base, X/R, and the line-to-line bus voltage.
- Generator data includes the generator kW rating, X"d, X/R, line-to-line voltage and per unit impedance on a 100 MVA base.

2. Motor Contribution Data

Motor Contribution Data includes the horsepower rating (base kVA rating), speed, subtransient reactance adjusted per the *First Cycle Duty* multipliers described in IEEE Std 141-1993 (Red Book), per-unit impedance on a 100 MVA base, and the bus voltage. X/R ratios for induction motors are obtained from IEEE Std C37.010-1999.

3. Feeder Data

Feeder data includes the following cable and bus data: length, impedance in ohms per 1,000 feet, and per-unit impedance on a 100 MVA base. Impedance values for conductors were obtained from Tables 4A-7 and 4A-8 of IEEE Std 141-1993 (Red Book).

4. Transformer Data

Transformer data includes the transformer kVA rating and per-unit impedance on a 100 MVA base.

Short-Circuit Input Report

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MOLOKAI IRRIGATION SYSTEM


Mar 23, 2015     10:51:51                                              Page 1
-------------------------------------------------------------------------------
 ALL INFORMATION PRESENTED IS FOR REVIEW, APPROVAL
 INTERPRETATION AND APPLICATION BY A REGISTERED ENGINEER ONLY
 SKM DISCLAIMS ANY RESPONSIBILITY AND LIABILITY RESULTING
 FROM THE USE AND INTERPRETATION OF THIS SOFTWARE.
 ------------------------------------------------------------------------------
 SKM POWER*TOOLS FOR WINDOWS
 INPUT DATA REPORT
 COPYRIGHT SKM SYSTEMS ANALYSIS, INC. 1995-2012
-------------------------------------------------------------------------------
 ALL PU VALUES ARE EXPRESSED ON A 100 MVA BASE.
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                                          FEEDER  INPUT  DATA
============================================================================================
CABLE          FEEDER FROM      FEEDER TO        QTY  VOLTS    LENGTH             FEEDER
NAME           NAME             NAME             /PH  L-L                     SIZE       TYPE
============================================================================================
CBL-0001       MECO H-FRAME     SW-1              1  12470    30.0  FEET     2/0     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.1020 + J  0.0504  Ohms/1000 ft      0.0020 + J 0.00097  PU
               Z0   Impedance: 0.1621 + J  0.1281  Ohms/1000 ft      0.0031 + J  0.0025  PU

CBL-0002       SW-1             HANDHOLE          1  12470   230.0  FEET     2/0     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.1020 + J  0.0504  Ohms/1000 ft      0.0151 + J  0.0075  PU
               Z0   Impedance: 0.1621 + J  0.1281  Ohms/1000 ft      0.0240 + J  0.0189  PU

CBL-0003       HANDHOLE         T-225KVA PRI      1  12470 24500.  FEET     2/0     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.1070 + J  0.0430  Ohms/1000 ft        1.69 + J  0.6775  PU
               Z0   Impedance: 0.7100 + J  0.0270  Ohms/1000 ft       11.19 + J  0.4254  PU

CBL-0004       T-225KVA SEC     WELL22 CNTLR      1    480    20.0  FEET     2/0     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.1010 + J  0.0426  Ohms/1000 ft      0.8767 + J  0.3698  PU
               Z0   Impedance: 0.1605 + J  0.1083  Ohms/1000 ft        1.39 + J  0.9401  PU

CBL-0005       T-225KVA PRI     T-300KVA PRI      1  12470 1400.0  FEET     2/0     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.1070 + J  0.0430  Ohms/1000 ft      0.0963 + J  0.0387  PU
               Z0   Impedance: 0.7100 + J  0.0270  Ohms/1000 ft      0.6392 + J  0.0243  PU

CBL-0006       T-300KVA SEC     SWBD-300KVA       2    480    15.0  FEET     350     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.0368 + J  0.0393  Ohms/1000 ft      0.1198 + J  0.1279  PU
               Z0   Impedance: 0.0585 + J  0.0999  Ohms/1000 ft      0.1904 + J  0.3252  PU

CBL-0007       T-300KVA PRI     T- 500KVA PRI     1  12470 2700.0  FEET     1/0     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.1280 + J  0.0507  Ohms/1000 ft      0.2222 + J  0.0880  PU
               Z0   Impedance: 0.2035 + J  0.1290  Ohms/1000 ft      0.3533 + J  0.2240  PU

CBL-0009       T-FARRINGTON S  MCC-FARRINGTON    1    480    55.0  FEET     250     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance: 0.0541 + J  0.0396  Ohms/1000 ft        1.29 + J  0.9453  PU
               Z0   Impedance: 0.0860 + J  0.1007  Ohms/1000 ft        2.05 + J    2.40  PU

CBL-0010       T-225KVA SEC     T-PG PRI          1    480    15.0  FEET      12     Copper
               Duct Material: Non-Magnetic
               +/-  Impedance:   1.87 + J  0.0892  Ohms/1000 ft       12.17 + J  0.5807  PU
               Z0   Impedance:   2.97 + J  0.2269  Ohms/1000 ft       19.35 + J    1.48  PU
```

TRANSFORMER INPUT DATA

```
===========================================================================================
TRANSFORMER    PRIMARY RECORD      VOLTS   * SECONDARY RECORD     VOLTS   FULL-LOAD   NOMINAL
NAME           NO NAME             L-L      NO NAME               L-L     KVA           KVA

===========================================================================================
T-225KVA       T-225KVA PRI   D  12470.0   T-225KVA SEC   YG    480.00  225.00       225.00
               Pos. Seq. Z%:     1.43 + J   5.57    (Zpu   6.35 + j  24.75 )   Shell Type
               Zero Seq. Z%:     1.43 + J   5.57    (Sec   6.35 + j  24.75 Pri  Open)
               Taps  Pri. 0.000 %  Sec. 0.000 %  Phase Shift (Pri. Leads Sec.):  30.00 Deg.

T-300KVA       T-300KVA PRI   D  12470.0   T-300KVA SEC   D     480.00  300.00       300.00
               Pos. Seq. Z%:     1.35 + J   5.59    (Zpu   4.49 + j  18.63 )   Shell Type
               Zero Seq. Z%:    9999. + J  9999.    (Pri  Open, Sec  Open)
               Taps  Pri. 0.000 %  Sec. 0.000 %  Phase Shift (Pri. Leads Sec.):  0.000 Deg.

T-500KVA       T- 500KVA PRI  D  12470.0   SWBD DIVERSION D     480.00  500.00       500.00
               Pos. Seq. Z%:    0.935 + J   4.39    (Zpu   1.87 + j   8.78 )   Shell Type
               Zero Seq. Z%:    9999. + J  9999.    (Pri  Open, Sec  Open)
               Taps  Pri. 0.000 %  Sec. 0.000 %  Phase Shift (Pri. Leads Sec.):  0.000 Deg.

T-FARRINGTON   T-FARRINGTON P D  12470.0   T-FARRINGTON S YG    480.00  112.50       112.50
               Pos. Seq. Z%:    0.423 + J   1.44    (Zpu   3.77 + j  12.79 )   Shell Type
               Zero Seq. Z%:    0.423 + J   1.44    (Sec   3.77 + j  12.79 Pri  Open)
               Taps  Pri. 0.000 %  Sec. 0.000 %  Phase Shift (Pri. Leads Sec.):  30.00 Deg.

T-P            SWBD-300KVA    D   480.00   PNL P          YG    208.00    9.00         9.00
               Pos. Seq. Z%:     3.23 + J   2.15    (Zpu  359.4 + j  239.0 )   Shell Type
               Zero Seq. Z%:     3.23 + J   2.15    (Sec  359.4 + j  239.0 Pri  Open)
               Taps  Pri. 0.000 %  Sec. 0.000 %  Phase Shift (Pri. Leads Sec.):  30.00 Deg.

T-PG           T-PG PRI       D   480.00   PNL PG         YG    240.00    3.00         3.00
               Pos. Seq. Z%:     1.42 + J   1.42    (Zpu  474.6 + j  472.5 )   Shell Type
               Zero Seq. Z%:     1.42 + J   1.42    (Sec  474.6 + j  472.5 Pri  Open)
               Taps  Pri. 0.000 %  Sec. 0.000 %  Phase Shift (Pri. Leads Sec.):  30.00 Deg.
```

TRANSFORMER INPUT DATA

```
===============================================================================================
TRANSFORMER    PRIMARY RECORD      VOLTS   * SECONDARY RECORD     VOLTS   FULL-LOAD   NOMINAL
NAME           NO NAME             L-L       NO NAME              L-L     KVA          KVA

===============================================================================================
T-W            SWBD DIVERSION D   480.00   PNL W          YG    208.00    9.00         9.00
               Pos. Seq. Z%:     3.23 + J   2.15    (Zpu  359.4 + j  239.0 )    Shell Type
               Zero Seq. Z%:     3.23 + J   2.15    (Sec  359.4 + j  239.0 Pri  Open)
               Taps  Pri. 0.000 %  Sec. 0.000 %  Phase Shift (Pri. Leads Sec.):  30.00 Deg.
```

```
                       GENERATION  CONTRIBUTION  DATA
=====================================================================================
BUS            CONTRIBUTION    VOLTAGE
NAME           NAME               L-L     MVA      X"d    X/R
=====================================================================================
MECO H-FRAME   UTIL-0001       12470.0   71.28
                  Three Phase           Contribution:    3300.00 AMPS        8.00
                  Single Line to Ground Contribution:    3300.00 AMPS        8.00
                  Pos  Sequence Impedance (100 MVA Base)  0.1740 + J     1.39 PU
                  Zero Sequence Impedance (100 MVA Base)  0.1740 + J     1.39 PU

T-FARRINGTON S UTIL-0003        480.00   12.30
                  Three Phase           Contribution:    14800.0 AMPS        8.00
                  Single Line to Ground Contribution:    14800.0 AMPS        8.00
                  Pos  Sequence Impedance (100 MVA Base)    1.01 + J     8.06 PU
                  Zero Sequence Impedance (100 MVA Base)    1.01 + J     8.06 PU
```

MOTOR CONTRIBUTION DATA

BUS NAME	CONTRIBUTION NAME	VOLTAGE L-L	BASE kVA	X"d	X/R	Motor Number
MCC-FARRINGTON	PUMP-1	480	50.00	0.1670	5.36	1.00
	Pos Sequence Impedance (100 MVA Base) 62.35 + j 334.00 PU					
MCC-FARRINGTON	PUMP-2	480	50.00	0.1670	5.36	1.00
	Pos Sequence Impedance (100 MVA Base) 62.35 + j 334.00 PU					
SWBD-300KVA	WELL 23	480	100.00	0.1670	8.56	1.00
	Pos Sequence Impedance (100 MVA Base) 19.51 + j 167.00 PU					
SWBD-300KVA	WELL 24	480	100.00	0.1670	8.56	1.00
	Pos Sequence Impedance (100 MVA Base) 19.51 + j 167.00 PU					
SWBD DIVERSION	PUMP #1	480	75.00	0.1670	7.10	1.00
	Pos Sequence Impedance (100 MVA Base) 31.34 + j 222.67 PU					
SWBD DIVERSION	PUMP #2	480	75.00	0.1670	7.10	1.00
	Pos Sequence Impedance (100 MVA Base) 31.34 + j 222.67 PU					
SWBD DIVERSION	PUMP #3	480	150.00	0.1670	10.8	1.00
	Pos Sequence Impedance (100 MVA Base) 10.23 + j 111.33 PU					
SWBD DIVERSION	PUMP #5	480	75.00	0.1670	7.10	1.00
	Pos Sequence Impedance (100 MVA Base) 31.34 + j 222.67 PU					
SWBD DIVERSION	PUMP #6	480	100.00	0.1670	8.56	1.00
	Pos Sequence Impedance (100 MVA Base) 19.51 + j 167.00 PU					
WELL22 CNTLR	WELL 22	480	100.00	0.1670	8.56	1.00
	Pos Sequence Impedance (100 MVA Base) 19.51 + j 167.00 PU					

B. APPENDIX B – SHORT-CIRCUIT RESULTS

```
MOLOKAI IRRIGATION SYSTEM

Mar 23, 2015     10:51:51

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ALL INFORMATION PRESENTED IS FOR REVIEW, APPROVAL
INTERPRETATION AND APPLICATION BY A REGISTERED ENGINEER ONLY
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------------------------------------------------------------------------------
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A_FAULT SHORT CIRCUIT ANALYSIS REPORT
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               T H R E E   P H A S E   F A U L T   R E P O R T
                  (FOR APPLICATION OF LOW VOLTAGE BREAKERS)
                        PRE FAULT VOLTAGE: 1.0000
                        MODEL TRANSFORMER TAPS: NO
==============================================================================

 MCC-FARRINGTON 3P Duty: 13.524 KA AT  -75.85 DEG (  11.24 MVA)  X/R:     3.98
                VOLTAGE:    480.   EQUIV. IMPEDANCE=  0.0050 + J  0.0199  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER   13.524 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA  14.331 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA  13.524 KA
                CONTRIBUTIONS:  PUMP-1             0.295 KA      ANG:   -79.43
                                PUMP-2             0.295 KA      ANG:   -79.43
                CBL-0009        T-FARRINGTON S    12.936 KA      ANG:   -75.68

 MECO H-FRAME   3P Duty:  3.444 KA AT  -82.72 DEG (  74.38 MVA)  X/R:     7.88
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  0.2650 + J  2.0737  OHMS
                CONTRIBUTIONS:  UTIL-0001          3.300 KA      ANG:   -82.87
                CBL-0001        SW-1               0.144 KA      ANG:  -259.13

 PNL P          3P Duty:  0.623 KA AT  -35.14 DEG (   0.22 MVA)  X/R:     0.71
                VOLTAGE:    208.   EQUIV. IMPEDANCE=  0.1576 + J  0.1109  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER    0.623 KA
                MOLDED CASE CIRCUIT BREAKER < 10KA   0.623 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA   0.623 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA   0.623 KA
                T-P             SWBD-300KVA        0.623 KA      ANG:  -215.14

 PNL PG         3P Duty:  0.344 KA AT  -45.20 DEG (   0.14 MVA)  X/R:     1.01
                VOLTAGE:    240.   EQUIV. IMPEDANCE=  0.2842 + J  0.2861  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER    0.344 KA
                MOLDED CASE CIRCUIT BREAKER < 10KA   0.344 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA   0.344 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA   0.344 KA
                T-PG            T-PG PRI           0.344 KA      ANG:   134.80

 PNL W          3P Duty:  0.633 KA AT  -34.38 DEG (   0.23 MVA)  X/R:     0.69
                VOLTAGE:    208.   EQUIV. IMPEDANCE=  0.1567 + J  0.1072  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER    0.633 KA
                MOLDED CASE CIRCUIT BREAKER < 10KA   0.633 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA   0.633 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA   0.633 KA
                T-W             SWBD DIVERSION     0.633 KA      ANG:   145.62

 SW-1           3P Duty:  3.441 KA AT  -82.65 DEG (  74.32 MVA)  X/R:     7.80
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  0.2678 + J  2.0751  OHMS
                CBL-0001        MECO H-FRAME       3.297 KA      ANG:   -82.80
                CBL-0002        HANDHOLE           0.144 KA      ANG:  -259.14
```

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               T H R E E   P H A S E   F A U L T   R E P O R T
                  (FOR APPLICATION OF LOW VOLTAGE BREAKERS)
                        PRE FAULT VOLTAGE: 1.0000
                        MODEL TRANSFORMER TAPS: NO
==============================================================================

 SWBD DIVERSION 3P Duty: 13.088 KA AT  -72.90 DEG (  10.88 MVA)  X/R:     4.08
                VOLTAGE:    480.   EQUIV. IMPEDANCE=  0.0062 + J  0.0202  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER   13.088 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA  13.949 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA  13.088 KA
                CONTRIBUTIONS:  PUMP #2           0.446 KA      ANG:   -81.99
                                PUMP #1           0.446 KA      ANG:   -81.99
                                PUMP #3           0.897 KA      ANG:   -84.75
                                PUMP #5           0.446 KA      ANG:   -81.99
                                PUMP #6           0.596 KA      ANG:   -83.34
                T-500KVA        T- 500KVA PRI    10.316 KA      ANG:  -250.10

 SWBD-300KVA    3P Duty:  6.695 KA AT  -74.76 DEG (   5.57 MVA)  X/R:     4.30
                VOLTAGE:    480.   EQUIV. IMPEDANCE=  0.0109 + J  0.0399  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER    6.695 KA
                MOLDED CASE CIRCUIT BREAKER < 10KA   8.529 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA   7.228 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA   6.695 KA
                CONTRIBUTIONS:  WELL 24           0.596 KA      ANG:   -83.34
                                WELL 23           0.596 KA      ANG:   -83.34
                CBL-0006        T-300KVA SEC      5.519 KA      ANG:  -252.92

 T- 500KVA PRI  3P Duty:  1.604 KA AT  -48.02 DEG (  34.64 MVA)  X/R:     1.39
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  3.0028 + J  3.3373  OHMS
                T-500KVA        SWBD DIVERSION    0.090 KA      ANG:    97.75
                CBL-0007        T-300KVA PRI      1.530 KA      ANG:   -46.12

 T-225KVA PRI   3P Duty:  1.778 KA AT  -50.59 DEG (  38.41 MVA)  X/R:     1.49
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  2.5701 + J  3.1280  OHMS
                CBL-0003        HANDHOLE          1.653 KA      ANG:   -47.91
                T-225KVA        T-225KVA SEC      0.020 KA      ANG:    97.74
                CBL-0005        T-300KVA PRI      0.128 KA      ANG:    98.08

 T-225KVA SEC   3P Duty:  4.890 KA AT  -74.48 DEG (   4.07 MVA)  X/R:     4.03
                VOLTAGE:    480.   EQUIV. IMPEDANCE=  0.0152 + J  0.0546  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER    4.890 KA
                MOLDED CASE CIRCUIT BREAKER < 10KA   6.131 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA   5.196 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA   4.890 KA
                CBL-0004        WELL22 CNTLR      0.595 KA      ANG:    96.90
                T-225KVA        T-225KVA PRI      4.303 KA      ANG:  -253.29

 T-300KVA PRI   3P Duty:  1.723 KA AT  -49.81 DEG (  37.21 MVA)  X/R:     1.47
```

```
                T H R E E   P H A S E   F A U L T   R E P O R T
                   (FOR APPLICATION OF LOW VOLTAGE BREAKERS)
                         PRE FAULT VOLTAGE: 1.0000
                         MODEL TRANSFORMER TAPS: NO
==============================================================================
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  2.6966 + J  3.1923  OHMS
                CBL-0007        T- 500KVA PRI      0.090 KA      ANG:    97.99
                T-300KVA        T-300KVA SEC       0.039 KA      ANG:    97.81
                CBL-0005        T-225KVA PRI       1.616 KA      ANG:   -47.38

 T-FARRINGTON P 3P Duty:  0.220 KA AT  -76.96 DEG (   4.74 MVA)  X/R:     4.32
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  7.3973 + J 31.9467  OHMS
                T-FARRINGTON    T-FARRINGTON S     0.220 KA      ANG:   103.04

 WELL22 CNTLR   3P Duty:  4.796 KA AT  -73.24 DEG (   3.99 MVA)  X/R:     3.80
                VOLTAGE:    480.   EQUIV. IMPEDANCE=  0.0167 + J  0.0553  OHMS
                LOW VOLTAGE POWER CIRCUIT BREAKER    4.796 KA
                MOLDED CASE CIRCUIT BREAKER < 10KA   5.926 KA
                MOLDED CASE CIRCUIT BREAKER < 20KA   5.022 KA
                MOLDED CASE CIRCUIT BREAKER > 20KA   4.796 KA
                CONTRIBUTIONS:  WELL 22            0.596 KA      ANG:   -83.34
                CBL-0004        T-225KVA SEC       4.210 KA      ANG:   -71.82
```

```
                  U N B A L A N C E D   F A U L T   R E P O R T
                    (FOR APPLICATION OF LOW VOLTAGE BREAKERS)
                          PRE FAULT VOLTAGE: 1.0000
                          MODEL TRANSFORMER TAPS: NO
==============================================================================
  LOCATION     FAULT      KA     X/R  EQUIVALENT (PU)  ASYM. KA AT 0.5 CYCLES
  VOLTAGE      DUTIES     (RMS)       FAULT IMPEDANCE  * MAX. RMS  AVG. RMS *
==============================================================================

MCC-FARRINGTON 3P Duty:  13.524    4. Z1=   8.8937        16.074    14.828
              SLG DUTY:  14.041    3. Z2=   8.8937        16.128
   480. VOLTS    LN/LN:  11.712       Z0=   7.9636
             LN/LN/GND: 14.328 ( 14.570 GND RETURN KA)

MECO H-FRAME   3P Duty:   3.444    8. Z1=   1.3444         4.749     4.124
              SLG DUTY:   3.394    8. Z2=   1.3444         4.685
 12470. VOLTS    LN/LN:   2.982       Z0=   1.4030
             LN/LN/GND:  3.417 (  3.347 GND RETURN KA)

PNL P          3P Duty:   0.623    1. Z1= 445.3551         0.623     0.623
              SLG DUTY:   0.630    1. Z2= 445.3551         0.630
   208. VOLTS    LN/LN:   0.540       Z0= 431.6679
             LN/LN/GND:  0.631 (  0.636 GND RETURN KA)

PNL PG         3P Duty:   0.344    1. Z1= 700.1603         0.344     0.344
              SLG DUTY:   0.349    1. Z2= 700.1603         0.349
   240. VOLTS    LN/LN:   0.298       Z0= 669.7261
             LN/LN/GND:  0.347 (  0.354 GND RETURN KA)

PNL W          3P Duty:   0.633    1. Z1= 438.8210         0.633     0.633
              SLG DUTY:   0.636    1. Z2= 438.8210         0.636
   208. VOLTS    LN/LN:   0.548       Z0= 431.6679
             LN/LN/GND:  0.637 (  0.640 GND RETURN KA)

SW-1           3P Duty:   3.441    8. Z1=   1.3455         4.736     4.116
              SLG DUTY:   3.390    8. Z2=   1.3455         4.669
 12470. VOLTS    LN/LN:   2.980       Z0=   1.4058
             LN/LN/GND:  3.414 (  3.341 GND RETURN KA)

SWBD DIVERSION 3P Duty:  13.088    4. Z1=   9.1905        15.640    14.393
              SLG DUTY:   0.000    1. Z2=   9.1905         0.000
   480. VOLTS    LN/LN:  11.334       Z0= INFINITE
             LN/LN/GND: 11.334 (  0.000 GND RETURN KA)

SWBD-300KVA    3P Duty:   6.695    4. Z1=  17.9652         8.100     7.415
              SLG DUTY:   0.000    1. Z2=  17.9652         0.000
   480. VOLTS    LN/LN:   5.798       Z0= INFINITE
             LN/LN/GND:  5.798 (  0.000 GND RETURN KA)
```

U N B A L A N C E D   F A U L T   R E P O R T

(FOR APPLICATION OF LOW VOLTAGE BREAKERS)
PRE FAULT VOLTAGE: 1.0000
MODEL TRANSFORMER TAPS: NO

LOCATION VOLTAGE	FAULT DUTIES	KA (RMS)	X/R	EQUIVALENT (PU) FAULT IMPEDANCE	ASYM. KA AT 0.5 CYCLES * MAX. RMS	AVG. RMS *
T- 500KVA PRI	3P Duty:	1.604	1.	Z1= 2.8870	1.621	1.612
	SLG DUTY:	0.796	0.	Z2= 2.8870	0.796	
12470. VOLTS	LN/LN:	1.389		Z0= 12.5548		
	LN/LN/GND:	1.547 (0.506 GND RETURN KA)				
T-225KVA PRI	3P Duty:	1.778	1.	Z1= 2.6035	1.804	1.791
	SLG DUTY:	0.878	0.	Z2= 2.6035	0.878	
12470. VOLTS	LN/LN:	1.540		Z0= 11.5351		
	LN/LN/GND:	1.723 (0.554 GND RETURN KA)				
T-225KVA SEC	3P Duty:	4.890	4.	Z1= 24.5975	5.827	5.369
	SLG DUTY:	4.828	4.	Z2= 24.5975	5.737	
480. VOLTS	LN/LN:	4.235		Z0= 25.5555		
	LN/LN/GND:	4.832 (4.766 GND RETURN KA)				
T-300KVA PRI	3P Duty:	1.723	1.	Z1= 2.6873	1.747	1.735
	SLG DUTY:	0.836	0.	Z2= 2.6873	0.836	
12470. VOLTS	LN/LN:	1.492		Z0= 12.1703		
	LN/LN/GND:	1.664 (0.526 GND RETURN KA)				
T-FARRINGTON P	3P Duty:	0.220	4.	Z1= 21.0879	0.220	0.243
	SLG DUTY:			Z2= 21.0879	0.000	
12470. VOLTS	LN/LN:	0.190		Z0= INFINITE		
	LN/LN/GND:	0.190 (0.000 GND RETURN KA)				
WELL22 CNTLR	3P Duty:	4.796	4.	Z1= 25.0807	5.638	5.226
	SLG DUTY:	4.686	4.	Z2= 25.0807	5.448	
480. VOLTS	LN/LN:	4.153		Z0= 26.8357		
	LN/LN/GND:	4.744 (4.582 GND RETURN KA)				

F A U L T S T U D Y S U M M A R Y
(FOR APPLICATION OF LOW VOLTAGE BREAKERS)
PRE FAULT VOLTAGE: 1.0000
MODEL TRANSFORMER TAPS: NO

BUS RECORD NO NAME	VOLTAGE L-L	A V A I L A B L E F A U L T D U T I E S (KA) 3 PHASE	X/R	LINE/GRND	X/R
MCC-FARRINGTON	480.	13.524	3.98	14.041	3.42
MECO H-FRAME	12470.	3.444	7.88	3.394	7.92
PNL P	208.	0.623	0.71	0.630	0.69
PNL PG	240.	0.344	1.01	0.349	1.00
PNL W	208.	0.633	0.69	0.636	0.68
SW-1	12470.	3.441	7.80	3.390	7.83
SWBD DIVERSION	480.	13.088	4.08	0.000	1.00
SWBD-300KVA	480.	6.695	4.30	0.000	1.00
T- 500KVA PRI	12470.	1.604	1.39	0.796	0.40
T-225KVA PRI	12470.	1.778	1.49	0.878	0.41
T-225KVA SEC	480.	4.890	4.03	4.828	3.98
T-300KVA PRI	12470.	1.723	1.47	0.836	0.40
T-FARRINGTON P	12470.	0.220	4.32		
WELL22 CNTLR	480.	4.796	3.80	4.686	3.61

18 FAULTED BUSES, 28 BRANCHES, 12 CONTRIBUTIONS
UNBALANCED FAULTS REQUESTED

*** SHORT CIRCUIT STUDY COMPLETE ***

```
     T H R E E   P H A S E   M O M E N T A R Y   D U T Y   R E P O R T
                         PRE FAULT VOLTAGE: 1.0000
                         MODEL TRANSFORMER TAPS: NO
 ==============================================================================

  MCC-FARRINGTON VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )

  MECO H-FRAME   E/Z:      3.444 KA AT  -82.72 DEG (  74.38 MVA)  X/R:     7.88
                 SYM*1.6:    5.510 KA      MOMENTARY BASED ON X/R:    4.749 KA
                 SYM*2.7:    9.298 KA          CREST BASED ON X/R:    8.140 KA
                 VOLTAGE:  12470.  EQUIV. IMPEDANCE=  0.2650 + J  2.0737  OHMS
                 CONTRIBUTIONS:  UTIL-0001          3.300 KA      ANG:   -82.87
                 CBL-0001        SW-1               0.144 KA      ANG:  -259.13

  PNL P          VOLTAGE:    208.  ( SEE LOW VOLTAGE REPORT )

  PNL PG         VOLTAGE:    240.  ( SEE LOW VOLTAGE REPORT )

  PNL W          VOLTAGE:    208.  ( SEE LOW VOLTAGE REPORT )

  SW-1           E/Z:      3.441 KA AT  -82.65 DEG (  74.32 MVA)  X/R:     7.80
                 SYM*1.6:    5.506 KA      MOMENTARY BASED ON X/R:    4.736 KA
                 SYM*2.7:    9.291 KA          CREST BASED ON X/R:    8.120 KA
                 VOLTAGE:  12470.  EQUIV. IMPEDANCE=  0.2678 + J  2.0751  OHMS
                 CBL-0001        MECO H-FRAME       3.297 KA      ANG:   -82.80
                 CBL-0002        HANDHOLE           0.144 KA      ANG:  -259.14

  SWBD DIVERSION VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )

  SWBD-300KVA    VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )

  T- 500KVA PRI  E/Z:      1.604 KA AT  -48.02 DEG (  34.64 MVA)  X/R:     1.39
                 SYM*1.6:    2.566 KA      MOMENTARY BASED ON X/R:    1.621 KA
                 SYM*2.7:    4.330 KA          CREST BASED ON X/R:    2.506 KA
                 VOLTAGE:  12470.  EQUIV. IMPEDANCE=  3.0028 + J  3.3373  OHMS
                 T-500KVA        SWBD DIVERSION     0.090 KA      ANG:    97.75
                 CBL-0007        T-300KVA PRI       1.530 KA      ANG:   -46.12

  T-225KVA PRI   E/Z:      1.778 KA AT  -50.59 DEG (  38.41 MVA)  X/R:     1.49
                 SYM*1.6:    2.845 KA      MOMENTARY BASED ON X/R:    1.804 KA
                 SYM*2.7:    4.802 KA          CREST BASED ON X/R:    2.821 KA
                 VOLTAGE:  12470.  EQUIV. IMPEDANCE=  2.5701 + J  3.1280  OHMS
                 CBL-0003        HANDHOLE           1.653 KA      ANG:   -47.91
                 T-225KVA        T-225KVA SEC       0.020 KA      ANG:    97.74
                 CBL-0005        T-300KVA PRI       0.128 KA      ANG:    98.08

  T-225KVA SEC   VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )
```

```
     T H R E E   P H A S E   M O M E N T A R Y   D U T Y   R E P O R T
                          PRE FAULT VOLTAGE: 1.0000
                          MODEL TRANSFORMER TAPS: NO
 ==============================================================================

  T-300KVA PRI   E/Z:      1.723 KA AT  -49.81 DEG (  37.21 MVA)  X/R:     1.47
                 SYM*1.6:    2.757 KA       MOMENTARY BASED ON X/R:    1.747 KA
                 SYM*2.7:    4.652 KA           CREST BASED ON X/R:    2.723 KA
                 VOLTAGE:  12470.   EQUIV. IMPEDANCE=  2.6966 + J  3.1923  OHMS
                 CBL-0007       T- 500KVA PRI      0.090 KA      ANG:    97.99
                 T-300KVA       T-300KVA SEC       0.039 KA      ANG:    97.81
                 CBL-0005       T-225KVA PRI       1.616 KA      ANG:   -47.38

  T-FARRINGTON P E/Z:      0.220 KA AT  -76.96 DEG (   4.74 MVA)  X/R:     4.32
                 SYM*1.6:    0.351 KA       MOMENTARY BASED ON X/R:    0.266 KA
                 SYM*2.7:    0.593 KA           CREST BASED ON X/R:    0.461 KA
                 VOLTAGE:  12470.   EQUIV. IMPEDANCE=  7.3973 + J 31.9467  OHMS
                 T-FARRINGTON    T-FARRINGTON S    0.220 KA      ANG:   103.04

  WELL22 CNTLR   VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )
```

```
      U N B A L A N C E D   M O M E N T A R Y   D U T Y   R E P O R T
                         PRE FAULT VOLTAGE: 1.0000
                         MODEL TRANSFORMER TAPS: NO
==============================================================================
  LOCATION     FAULT       E/Z    X/R  EQUIVALENT       MOMENTARY FAULT DUTIES
  VOLTAGE      TYPE        KA          IMPEDANCE (PU)   E/Z * 1.6  @ 0.5 CYCLE
==============================================================================

                3P Duty:   3.44    7.9 Z1=  1.3444        5.51       4.75
MECO H-FRAME   SLG DUTY:   3.39    7.9 Z2=  1.3444        5.43       4.69
 12470.     VOLTS LN/LN:   2.98        Z0=  1.4030
              LN/LN/GND:   3.42 (    3.35 GND RETURN KA)

                3P Duty:   3.44    7.8 Z1=  1.3455        5.51       4.74
SW-1           SLG DUTY:   3.39    7.8 Z2=  1.3455        5.42       4.67
 12470.     VOLTS LN/LN:   2.98        Z0=  1.4058
              LN/LN/GND:   3.41 (    3.34 GND RETURN KA)

                3P Duty:   1.60    1.4 Z1=  2.8870        2.57       1.62
T- 500KVA PRI  SLG DUTY:   0.80    0.4 Z2=  2.8870        1.27       0.80
 12470.     VOLTS LN/LN:   1.39        Z0= 12.5548
              LN/LN/GND:   1.55 (    0.51 GND RETURN KA)

                3P Duty:   1.78    1.5 Z1=  2.6035        2.85       1.80
T-225KVA PRI   SLG DUTY:   0.88    0.4 Z2=  2.6035        1.40       0.88
 12470.     VOLTS LN/LN:   1.54        Z0= 11.5351
              LN/LN/GND:   1.72 (    0.55 GND RETURN KA)

                3P Duty:   1.72    1.5 Z1=  2.6873        2.76       1.75
T-300KVA PRI   SLG DUTY:   0.84    0.4 Z2=  2.6873        1.34       0.84
 12470.     VOLTS LN/LN:   1.49        Z0= 12.1703
              LN/LN/GND:   1.66 (    0.53 GND RETURN KA)

                3P Duty:   0.22    4.3 Z1= 21.0879        0.35       0.27
T-FARRINGTON P SLG DUTY:                Z2= 21.0879
 12470. VOLTS LN/LN        0.19        Z0= INFINITE
              LN/LN/GND:   0.19 (    0.00 GND RETURN KA)
```

M O M E N T A R Y D U T Y S U M M A R Y R E P O R T

PRE FAULT VOLTAGE: 1.0000
MODEL TRANSFORMER TAPS: NO
SOLUTION METHOD : E/Z

BUS RECORD NO NAME	VOLTAGE L-L	* 3 P H A S E * KA	X/R	* * * SLG * * * KA	X/R
MECO H-FRAME	12470.	4.749	7.88	4.685	7.92
SW-1	12470.	4.736	7.80	4.669	7.83
T- 500KVA PRI	12470.	1.621	1.39	0.796	0.40
T-225KVA PRI	12470.	1.804	1.49	0.878	0.41
T-300KVA PRI	12470.	1.747	1.47	0.836	0.40
T-FARRINGTON P	12470.	0.266	4.32		

7 FAULTED BUSES, 28 BRANCHES, 12 CONTRIBUTIONS
UNBALANCED FAULTS REQUESTED

*** SHORT CIRCUIT STUDY COMPLETE ***

```
  T H R E E   P H A S E   I N T E R R U P T I N G   D U T Y   R E P O R T
                         PRE FAULT VOLTAGE: 1.0000
                         MODEL TRANSFORMER TAPS: NO
                         NACD OPTION:  INTERPOLATED
==============================================================================

 MCC-FARRINGTON VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )

 MECO H-FRAME   E/Z:      3.365 KA AT  -82.85 DEG (  72.68 MVA)  X/R:     7.97
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  0.2664 + J  2.1229  OHMS
                CONTRIBUTIONS:  UTIL-0001          3.300 KA      ANG:   -82.87
                CBL-0001        SW-1               0.065 KA      ANG:  -261.37

                GENERATOR NAME -- AT BUS --    KA    VOLTS PU  LOCAL/REMOTE
            UTIL-0001                      3.300     0.00         R
                TOTAL REMOTE:     3.300 KA  NACD RATIO:  0.9807

                                SYM2     SYM3     SYM5     SYM8
                MULT. FACT:    1.000    1.000    1.000    1.001
                DUTY (KA) :    3.365    3.365    3.365    3.368

                                TOT2     TOT3     TOT5     TOT8
                MULT. FACT:    1.146    1.023    1.000    1.000
                DUTY (KA) :    3.857    3.441    3.365    3.365

 PNL P          VOLTAGE:    208.  ( SEE LOW VOLTAGE REPORT )

 PNL PG         VOLTAGE:    240.  ( SEE LOW VOLTAGE REPORT )

 PNL W          VOLTAGE:    208.  ( SEE LOW VOLTAGE REPORT )

 SW-1           E/Z:      3.362 KA AT  -82.77 DEG (  72.62 MVA)  X/R:     7.89
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  0.2694 + J  2.1243  OHMS
                CBL-0001        MECO H-FRAME       3.297 KA      ANG:   -82.80
                CBL-0002        HANDHOLE           0.065 KA      ANG:  -261.38

                GENERATOR NAME -- AT BUS --    KA    VOLTS PU  LOCAL/REMOTE
            UTIL-0001                      3.297     0.00         R
                TOTAL REMOTE:     3.297 KA  NACD RATIO:  0.9807

                                SYM2     SYM3     SYM5     SYM8
                MULT. FACT:    1.000    1.000    1.000    1.001
                DUTY (KA) :    3.362    3.362    3.362    3.364

                                TOT2     TOT3     TOT5     TOT8
                MULT. FACT:    1.144    1.021    1.000    1.000
                DUTY (KA) :    3.845    3.434    3.362    3.362

 SWBD DIVERSION VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )
```

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     T H R E E   P H A S E   I N T E R R U P U T I N G   D U T Y   R E P O R T
                          PRE FAULT VOLTAGE: 1.0000
                          MODEL TRANSFORMER TAPS: NO
==============================================================================

 SWBD-300KVA    VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )

 T- 500KVA PRI  E/Z:      1.538 KA AT  -46.48 DEG (  33.23 MVA)  X/R:     1.20
                VOLTAGE:  12470.  EQUIV. IMPEDANCE=  3.2224 + J  3.3934  OHMS
                T-500KVA       SWBD DIVERSION     0.040 KA      ANG:    97.26
                CBL-0007       T-300KVA PRI       1.506 KA      ANG:   -45.58

                GENERATOR NAME -- AT BUS --    KA    VOLTS PU  LOCAL/REMOTE
            UTIL-0001                      1.487     0.70         R
                TOTAL REMOTE:     1.487 KA  NACD RATIO:  0.9665

                               SYM2     SYM3     SYM5     SYM8
                MULT. FACT:    1.000    1.000    1.000    1.000
                DUTY (KA) :    1.538    1.538    1.538    1.538

                               TOT2     TOT3     TOT5     TOT8
                MULT. FACT:    1.005    1.000    1.000    1.000
                DUTY (KA) :    1.546    1.538    1.538    1.538

 T-225KVA PRI   E/Z:      1.708 KA AT  -49.17 DEG (  36.89 MVA)  X/R:     1.30
                VOLTAGE:  12470.  EQUIV. IMPEDANCE=  2.7559 + J  3.1896  OHMS
                CBL-0003       HANDHOLE           1.653 KA      ANG:   -47.91
                T-225KVA       T-225KVA SEC       0.009 KA      ANG:    97.13
                CBL-0005       T-300KVA PRI       0.057 KA      ANG:    97.37

                GENERATOR NAME -- AT BUS --    KA    VOLTS PU  LOCAL/REMOTE
            UTIL-0001                      1.653     0.66         R
                TOTAL REMOTE:     1.653 KA  NACD RATIO:  0.9681

                               SYM2     SYM3     SYM5     SYM8
                MULT. FACT:    1.000    1.000    1.000    1.000
                DUTY (KA) :    1.708    1.708    1.708    1.708

                               TOT2     TOT3     TOT5     TOT8
                MULT. FACT:    1.006    1.000    1.000    1.000
                DUTY (KA) :    1.719    1.708    1.708    1.708

 T-225KVA SEC   VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )

 T-300KVA PRI   E/Z:      1.654 KA AT  -48.32 DEG (  35.71 MVA)  X/R:     1.27
                VOLTAGE:  12470.  EQUIV. IMPEDANCE=  2.8950 + J  3.2521  OHMS
                CBL-0007       T- 500KVA PRI      0.040 KA      ANG:    97.36
                T-300KVA       T-300KVA SEC       0.017 KA      ANG:    97.17
                CBL-0005       T-225KVA PRI       1.607 KA      ANG:   -47.17
```

```
  T H R E E   P H A S E   I N T E R R U P T I N G   D U T Y   R E P O R T
                         PRE FAULT VOLTAGE: 1.0000
                         MODEL TRANSFORMER TAPS: NO
                         NACD OPTION:  INTERPOLATED
==============================================================================

                GENERATOR NAME -- AT BUS --   KA    VOLTS PU  LOCAL/REMOTE
            UTIL-0001                      1.600     0.67         R
                TOTAL REMOTE:     1.600 KA  NACD RATIO:  0.9675

                               SYM2     SYM3     SYM5     SYM8
                MULT. FACT:    1.000    1.000    1.000    1.000
                DUTY (KA) :    1.654    1.654    1.654    1.654

                               TOT2     TOT3     TOT5     TOT8
                MULT. FACT:    1.006    1.000    1.000    1.000
                DUTY (KA) :    1.663    1.654    1.654    1.654

 T-FARRINGTON P E/Z:      0.218 KA AT  -77.04 DEG (   4.70 MVA)  X/R:     4.35
                VOLTAGE:  12470.   EQUIV. IMPEDANCE=  7.4143 + J 32.2301  OHMS
                T-FARRINGTON    T-FARRINGTON S     0.218 KA      ANG:  102.96

                GENERATOR NAME -- AT BUS --   KA    VOLTS PU  LOCAL/REMOTE
            UTIL-0003                      0.214     0.63         R
                TOTAL REMOTE:     0.214 KA  NACD RATIO:  0.9844

                               SYM2     SYM3     SYM5     SYM8
                MULT. FACT:    1.000    1.000    1.000    1.000
                DUTY (KA) :    0.218    0.218    0.218    0.218

                               TOT2     TOT3     TOT5     TOT8
                MULT. FACT:    1.044    1.000    1.000    1.000
                DUTY (KA) :    0.227    0.218    0.218    0.218

 WELL22 CNTLR   VOLTAGE:    480.  ( SEE LOW VOLTAGE REPORT )
```

U N B A L A N C E D   I N T E R R U P T I N G   D U T Y   R E P O R T

PRE FAULT VOLTAGE: 1.0000
MODEL TRANSFORMER TAPS: NO
NACD OPTION: INTERPOLATED

LOCATION	FAULT TYPE	E/Z KA	X/R		ANSI AC/DC DECREMENT FACT. 3 PHASE	SLG	INTERRUPTING DUTIES (KA) 3 PHASE	SLG
MECO H-FRAME	3P Duty:	3.37	8.0	SYM2:	1.00	1.00	3.37	3.34
VOLTS: 12470.0	SLG:	3.34	8.0	SYM3:	1.00	1.00	3.37	3.34
NACD: 0.981	LN/LN:	2.91		SYM5:	1.00	1.00	3.37	3.34
	LN/LN/GND:	3.35		SYM8:	1.00	1.00	3.37	3.35
	GND RETURN:	3.32		TOT2:	1.15	1.15	3.86	3.83
	Z1(PU):	1.37589		TOT3:	1.02	1.02	3.44	3.42
	Z2(PU):	1.37589		TOT5:	1.00	1.00	3.37	3.34
	Z0(PU):	1.40300		TOT8:	1.00	1.00	3.37	3.34
SW-1	3P Duty:	3.36	7.9	SYM2:	1.00	1.00	3.36	3.34
VOLTS: 12470.0	SLG:	3.34	7.9	SYM3:	1.00	1.00	3.36	3.34
NACD: 0.981	LN/LN:	2.91		SYM5:	1.00	1.00	3.36	3.34
	LN/LN/GND:	3.35		SYM8:	1.00	1.00	3.36	3.34
	GND RETURN:	3.32		TOT2:	1.14	1.14	3.85	3.82
	Z1(PU):	1.37705		TOT3:	1.02	1.02	3.43	3.41
	Z2(PU):	1.37705		TOT5:	1.00	1.00	3.36	3.34
	Z0(PU):	1.40585		TOT8:	1.00	1.00	3.36	3.34
T- 500KVA PRI	3P Duty:	1.54	1.2	SYM2:	1.00	1.00	1.54	0.78
VOLTS: 12470.0	SLG:	0.78	0.4	SYM3:	1.00	1.00	1.54	0.78
NACD: 0.966	LN/LN:	1.33		SYM5:	1.00	1.00	1.54	0.78
	LN/LN/GND:	1.49		SYM8:	1.00	1.00	1.54	0.78
	GND RETURN:	0.50		TOT2:	1.00	1.00	1.55	0.78
	Z1(PU):	3.00940		TOT3:	1.00	1.00	1.54	0.78
	Z2(PU):	3.00940		TOT5:	1.00	1.00	1.54	0.78
	Z0(PU):	12.55485		TOT8:	1.00	1.00	1.54	0.78
T-225KVA PRI	3P Duty:	1.71	1.3	SYM2:	1.00	1.00	1.71	0.86
VOLTS: 12470.0	SLG:	0.86	0.4	SYM3:	1.00	1.00	1.71	0.86
NACD: 0.968	LN/LN:	1.48		SYM5:	1.00	1.00	1.71	0.86
	LN/LN/GND:	1.66		SYM8:	1.00	1.00	1.71	0.86
	GND RETURN:	0.55		TOT2:	1.01	1.00	1.72	0.86
	Z1(PU):	2.71078		TOT3:	1.00	1.00	1.71	0.86
	Z2(PU):	2.71078		TOT5:	1.00	1.00	1.71	0.86
	Z0(PU):	11.53509		TOT8:	1.00	1.00	1.71	0.86

```
   U N B A L A N C E D   I N T E R R U P T I N G   D U T Y   R E P O R T
                         PRE FAULT VOLTAGE: 1.0000
                         MODEL TRANSFORMER TAPS: NO
                         NACD OPTION:  INTERPOLATED
==============================================================================
  LOCATION        FAULT    E/Z    X/R        ANSI AC/DC        INTERRUPTING
                  TYPE     KA                DECREMENT FACT.   DUTIES  (KA)
                                             3 PHASE    SLG    3 PHASE  SLG
==============================================================================

 T-300KVA PRI   3P Duty:   1.65     1.3 SYM2:    1.00    1.00    1.65    0.82
  VOLTS: 12470.0    SLG:   0.82     0.4 SYM3:    1.00    1.00    1.65    0.82
   NACD:  0.967   LN/LN:   1.43         SYM5:    1.00    1.00    1.65    0.82
              LN/LN/GND:   1.60         SYM8:    1.00    1.00    1.65    0.82
             GND RETURN:   0.52         TOT2:    1.01    1.00    1.66    0.82
                 Z1(PU):       2.79996 TOT3:    1.00    1.00    1.65    0.82
                 Z2(PU):       2.79996 TOT5:    1.00    1.00    1.65    0.82
                 Z0(PU):      12.17026 TOT8:    1.00    1.00    1.65    0.82

 T-FARRINGTON P 3P Duty:   0.22     4.3 SYM2:    1.00            0.22
  VOLTS: 12470.0    SLG:                SYM3:    1.00            0.22
   NACD:  0.984   LN/LN:   0.19         SYM5:    1.00            0.22
              LN/LN/GND:   0.19         SYM8:    1.00            0.22
             GND RETURN:                TOT2:    1.04            0.23
                 Z1(PU):      21.26802 TOT3:    1.00            0.22
                 Z2(PU):      21.26802 TOT5:    1.00            0.22
                 Z0(PU):                TOT8:    1.00            0.22
```

I N T E R R U P T I N G D U T Y S U M M A R Y R E P O R T

PRE FAULT VOLTAGE: 1.0000
MODEL TRANSFORMER TAPS: NO
NACD OPTION: INTERPOLATED

BUS RECORD NO NAME	VOLTAGE L-L	NACD RATIO	* 3 P H A S E * E/Z KA	X/R	* * * S L G * * * E/Z KA	X/R
MECO H-FRAME	12470.	0.981	3.365	7.97	3.343	7.98
SW-1	12470.	0.981	3.362	7.89	3.339	7.89
T- 500KVA PRI	12470.	0.966	1.538	1.20	0.783	0.40
T-225KVA PRI	12470.	0.968	1.708	1.30	0.864	0.41
T-300KVA PRI	12470.	0.967	1.654	1.27	0.823	0.39
T-FARRINGTON P	12470.	0.984	0.218	4.35		

7 FAULTED BUSES, 28 BRANCHES, 12 CONTRIBUTIONS
UNBALANCED FAULTS REQUESTED

*** SHORT CIRCUIT STUDY COMPLETE ***

C. APPENDIX C – UTILITY CORRESPONDENCE

See letter/email from Mr. Sakamoto at MECO Utility stating available fault current information on the attached sheet.

Dennis Toba

From: Sakamoto, Keith [keith.sakamoto@mauielectric.com]
Sent: Thursday, September 13, 2012 1:03 PM
To: Dennis Toba
Subject: RE: (Pn 26157) DOA Molokai Irrigation Tunnel Project - MECO Short Circuit Current Request

Hi Dennis,

We wouldn't anticipate the fault level to be more than 3300 amps.

Thanks,

Keith Sakamoto
Design Planner

Maui Electric Company, Ltd.
210 W. Kamehameha Ave.
Kahului, HI 96732

PH: 872-3294
FAX: 871-2322

From: Dennis Toba [mailto:DToba@rnsha.com]
Sent: Tuesday, September 11, 2012 7:15 AM
To: Sakamoto, Keith
Subject: RE: (Pn 26157) DOA Molokai Irrigation Tunnel Project - MECO Short Circuit Current Request

Hi Keith,

Thanks, I appreciate it.

Please feel free to contact me should you have any questions.

Best Regards,

Dennis Toba, P.E.
Ronald N.S. Ho & Associates, Inc.
2153 North King Street, Suite 201, Honolulu, Hawaii 96819, Ph. No. (808) 941-0577 , Fax No. (808) 945-2646

From: Sakamoto, Keith [mailto:keith.sakamoto@mauielectric.com]
Sent: Tuesday, September 11, 2012 7:00 AM
To: Dennis Toba
Subject: RE: (Pn 26157) DOA Molokai Irrigation Tunnel Project - MECO Short Circuit Current Request

Let me look into it and I'll let you know.

Thanks

Keith Sakamoto
Design Planner

Maui Electric Company, Ltd.
210 W. Kamehameha Ave.

Nacional, Melanio B

From: Kim, David C. <david.kim@mauielectric.com>
Sent: Wednesday, January 23, 2013 4:45 PM
To: Dennis Toba
Subject: RE: (Pn 26157/M) Molokai Irrigation System - Farrington Avenue and Ala Ekahi Street

Hi Dennis,

For your inquiry on November 21, 2012…
Please see comments in red.

For your inquiry on December 26, 2012…
Items 1 and 2, has been provided with your questions on November 21, 2012.
Item 3, has been provided with you questions on September 19, 2012.

Thank you,
David

David Kim
Customer Planner
Engineering Department

Maui Electric Company, Ltd.
210 West Kamehameha Avenue
Kahului, HI 967333
808-872-3214

From: Dennis Toba [mailto:DToba@rnsha.com]
Sent: Wednesday, December 26, 2012 12:06 PM
To: Kim, David C.
Subject: RE: (Pn 26157/M) Molokai Irrigation System - Farrington Avenue and Ala Ekahi Street

Hi David,

I had to add item 3 below. In addition to the information that I requested in my email below, could you also please include information on the Farrington Avenue service being requested by the company that is performing the arc-fault calculations.

1. 12.47kV Metering Point and Utility transformer primary terminal that feeds the 480V MCC (shown in drawing E-4.2) 's maximum and minimum three phase and single-line-to-ground available fault current with associated x/r ratios.
2. For utility transformer that feeds the 480V MCC shown in drawing E-4.2, provide the transformer size, winding connection (i.e. delta pri/wye sec etc.), neutral-ground connection (solid? Resistor value?), percent impedance (%Z), voltage ratings etc.
3. Provide the phase & ground overcurrent device upstream of the 12.47kV Metering Point (E-4.5) and 480V Motor Control Center (E-4.2) (if fuse, need fuse manufacturer, type, amp rating, speed rating, and nominal system voltage; if relay, need phase and ground overcurrent relay manufacturers, style numbers, CT ratios, existing adjustable settings, and setting ranges).

PDF's of sheets E-4.2 and E-4.5 are attached for your reference. Keith Sakamoto is providing the requested information on the other service shown on sheet E-4.5.

Please feel free to contact me should you have any questions.

Best Regards,

Dennis Toba, P.E.
Ronald N.S. Ho & Associates, Inc.
2153 North King Street, Suite 201, Honolulu, Hawaii 96819, Ph. No. (808) 941-0577 , Fax No. (808) 945-2646
e-mail: dtoba@rnsha.com
Go Green! Print this email only when necessary.

From: Kim, David C. [mailto:david.kim@mauielectric.com]
Sent: Monday, December 10, 2012 7:57 AM
To: Dennis Toba
Subject: RE: (Pn 26157/M) Molokai Irrigation System - Farrington Avenue and Ala Ekahi Street

Hi Dennis,

At this time, we are having our crew on Molokai verify some information for us. I will follow up with them. I will get back to you and respond to your inquiry as soon as possible. Thank you for your patience.

Happy Holidays,
David

David Kim
Customer Planner
Engineering Department

Maui Electric Company, Ltd.
210 West Kamehameha Avenue
Kahului, HI 967333
808-872-3214

From: Dennis Toba [mailto:DToba@rnsha.com]
Sent: Sunday, December 09, 2012 9:22 AM
To: Kim, David C.
Subject: FW: (Pn 26157/M) Molokai Irrigation System - Farrington Avenue and Ala Ekahi Street

Hi David,

I'm following up on the status of some information I requested last month. Could you please let me know of the status? This is for the service to the DOA pump station at Farrington Ave and Ala Ekahi Street on Molokai.

Please feel free to contact me should you have any questions.

Best Regards,

Dennis Toba, P.E.
Ronald N.S. Ho & Associates, Inc.
2153 North King Street, Suite 201, Honolulu, Hawaii 96819, Ph. No. (808) 941-0577 , Fax No. (808) 945-2646
e-mail: dtoba@rnsha.com
Go Green! Print this email only when necessary.

From: Dennis Toba [mailto:DToba@rnsha.com]
Sent: Wednesday, November 21, 2012 11:28 AM

To: 'Kim, David C.'
Subject: RE: (Pn 26157/M) Molokai Irrigation System - Farrington Avenue and Ala Ekahi Street

Hi David,

Sorry, I have another favor to ask. The arc flash calculations got too complicated so I had to hire a mainland company to assist me with the calculations at the Molokai irrigation tunnel. Could you please provide the information Eaton Corporation is requesting below? The information in blue is what you provided previously.

Utility Data:
1.) Provide information on the fuses at the fused cutouts that feed the pole mounted transformers at the Farrington Avenue Pump Station site:
a. manufacturer: Kearney
b. type: N
c. amp rating: Typically, we install 10N fuses for a transformer of this size.
d. speed rating: Based on N-type characteristics.
e. nominal system voltage: 12470V Wye, but transformer is connected 12470 Delta.
f. maximum (14,800A) and minimum three phase available fault current with associated x/r ratios: Unfortunately, we do not have a model to generate this information.
g. single-line-to-ground available fault current with associated x/r ratios: Unfortunately, we do not have a model to generate this information.
h. transformer size (3) 37.5 kVA
i. winding connection (i.e. delta pri / wye sec): Delta-Wye
j. neutral-ground connection (solid? Resistor value?) Since the system neutral does not extend to the transformer, there is no connection between neutral and ground.
k. percent impedance (%Z): 1.5%
l. voltage ratings: 12470V – 277/480V; Please note that though the transformer secondary is configured as a grounded wye, the requested service is 3-phase, 3-wire, 480V; therefore the configured service provided to the customer is an ungrounded wye.

The electrical contractor has to gather the information on the DOA equipment so if you could provide the information in the next couple of weeks I would greatly appreciate it.

In the meantime I hope you have a Happy Thanksgiving.

Please feel free to contact me should you have any questions.

Best Regards,

Dennis Toba, P.E.
Ronald N.S. Ho & Associates, Inc.
2153 North King Street, Suite 201, Honolulu, Hawaii 96819, Ph. No. (808) 941-0577 , Fax No. (808) 945-2646
e-mail: dtoba@rnsha.com

From: Kim, David C. [mailto:dckim@mauielectric.com]
Sent: Friday, September 28, 2012 11:39 AM
To: Dennis Toba
Subject: RE: (Pn 26157/M) Molokai Irrigation System - Farrington Avenue and Ala Ekahi Street

Hi Dennis,

As requested:

1. The calculated secondary short circuit current is 14,800A.
2. Our records show that the transformers are 3-37.5 kVA polemounts, configured as 3ph, 3-wire, 480 delta.

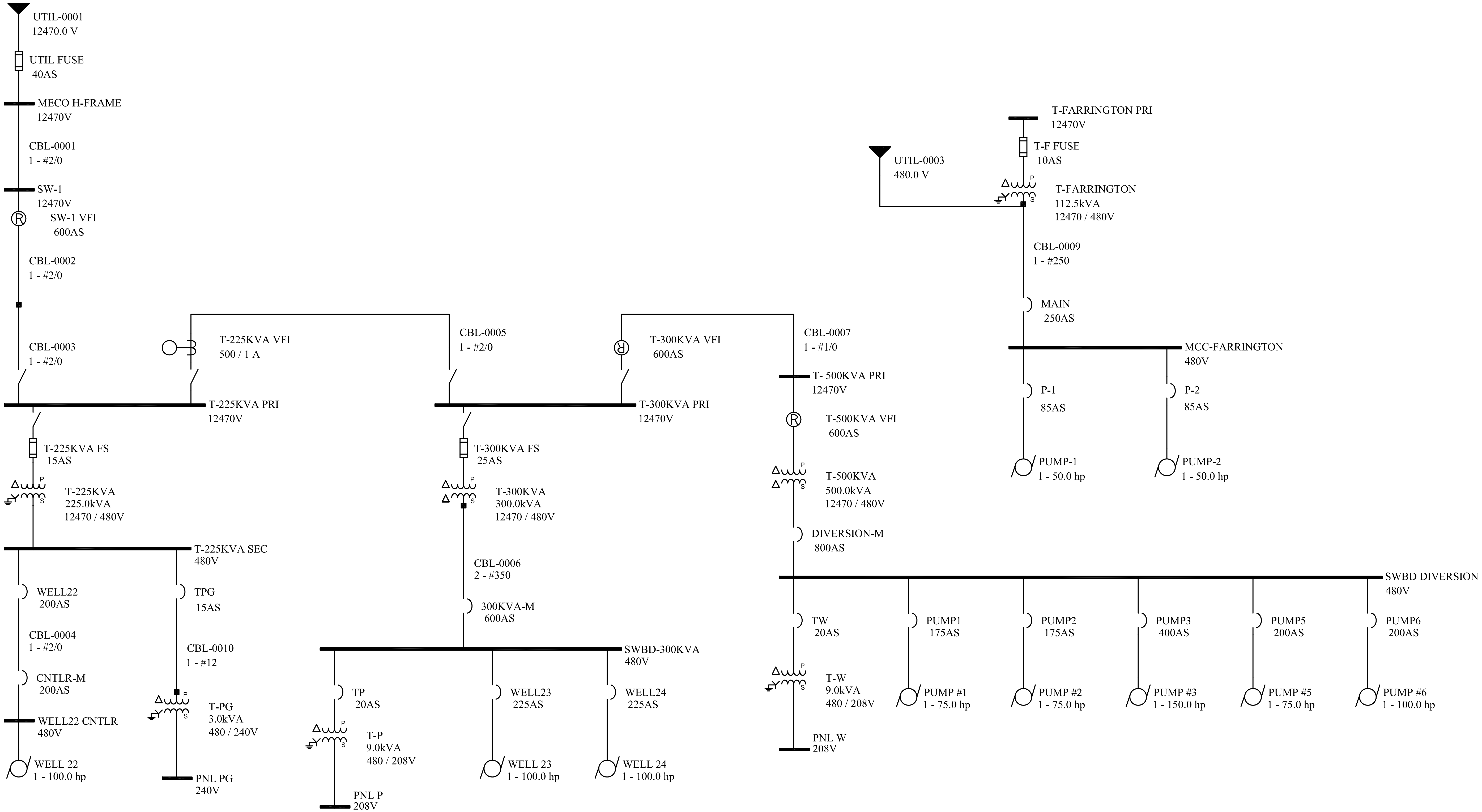
If you should have any other questions, please let me know.

D. APPENDIX D – ONE-LINE DIAGRAM

See power system study one-line diagram on the attached sheet.

Table D.1 – One-Line Diagram Index

One-Line Diagram Name	Page Number	One-Line Diagram Description
E-4.5	1 of 1	Facility System One Line Diagram



REVISION 02			

DFTR: Nacional	DATE: 3/23/2015	EATON Electrical Services & Systems	
ENGR: Nacional	DATE: 3/23/2015	TITLE: MOLOKAI IRRIGATION SYSTEM WAIKOLU TUNNEL, MOLOKAI, HAWAII	
SCALE: NONE		TYPE: Arc Flash Study	DWG TYPE
CAD FILENAME: E-4.5	PRODUCT CODE: U0160	REVISION: 02	G.O.: ESN6583
DWG: E-4.5	SHEET 1 OF 01		