Power System Study
for the
Pebble #2 Lift Station
Las Vegas, Nevada

Coordination Study
and
Arc Flash Analysis

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EXECUTIVE SUMMARY

Each aspect of the study, its pertinent results, and recommendations are summarized below. Detailed discussions appear later in each respective section of this report.

1. The **Coordination Study** found that the majority of the adjustable protective devices could be set to provide the greatest selectivity and minimize overall system impact in the event of a fault. As a result, it is recommended that all adjustable low voltage (277/480V through 120/208V) breakers be set and tested at the recommended settings.

    - A complete listing of all breaker settings can be found in the *Appendix / Coordination Study - Analysis/Tables* section of this report.

2. The **Arc Flash Study** resulted in PPE requirements that are reasonable values by which field personnel can comply with on a day to day basis. PPE requirements are primarily driven by breaker settings determined in the **Coordination Study**. Arc flash data was not calculated for buses upstream of the utility main disconnect because these values are dependent on utility fuse type and rating values which are not under the customer's control for sizing and maintenance purposes

    - It is highly recommended that all *coordination settings* documented in this report be followed, set, and remain unchanged to maintain the listed PPE requirements for each piece of equipment during the course of operation. PQTSi assumes no liability for changes to settings by field personnel that do not follow those listed in the documented coordination settings portion of this report.

COORDINATION STUDY INTRODUCTION

Introduction

The purpose of a coordination study is to properly select the circuit protective devices and to provide coordinated settings for adjustable protection devices in the facility that are within the scope of the study. The scope of this study includes the 480V utility service transformer through the utility service disconnect, a 480V MCC, and a variety of 277/480V panel boards, transformers and 120/208V panel boards. This study includes a tabulation of all appropriate feeder breaker settings.

The protective device ratings and settings were chosen to provide a reasonable compromise, based on a thorough engineering evaluation, between the often-conflicting goals of maximum protection and greatest service continuity. Judgments were made as to the best balance between these factors. When a balance is attained, the protective system is described as being "coordinated". It is not always possible to obtain the desired degree of system and equipment protection in a selective fashion. Selectivity means that for a fault at a given location, only the protective device nearest the fault will operate to isolate the fault from the circuit. Other "upstream" devices see the fault but allow the "downstream" device to operate first.

The Coordination Study's methods and recommendations are in conformance with the National Electrical Code (NEC), ANSI/IEEE Standard 242-1986 (IEEE Buff Book), and accepted industry practice. A general explanation of the methods used for this study is found under this tab in a section entitled *Procedures.*

The Coordination Study section of the report is organized as follows, *Compliance with Codes and Standards*, *Procedures*, and *General Discussion of Protective Devices.* The next section is titled *Coordination Study - Analysis* and includes the specific discussion and recommendations for the *Pebble #2 Lift Station* project. Time Current Curves used during the evaluation of this particular electrical distribution system are included in the *Appendix*.

Compliance with Codes and Standards

The following discussion addresses the study's compliance with the National Electric Code and ANSI/IEEE Standards.

Lack of selectivity normally occurs with the **use of molded-case circuit breakers and fuses** for both feeder protection and branch circuit protection. Underwriter's Laboratory standard (UL489) requires that the molded-case circuit breakers incorporate an instantaneous trip. This provides self-protection for the molded-case breaker. At high levels of fault current, the instantaneous trip sensor of both the upstream substation feeder breaker and the downstream molded-case breaker or fuse will sense the fault current. Either or both may trip. This lack of selectivity occurs under severe fault conditions when molded-case breakers or fuses are applied as feeder protective devices. It should also be noted that utilizing series rated combinations of circuit breakers would also compromise selectivity.

The electrical system is examined to find areas that do not conform to the current (2002) version of the **National Electric Code (NEC)**. The NEC is not necessarily enforced retroactively and it is not possible to determine the provisions of the NEC that were in force at the time that a particular installation was made. However, since the NEC provisions cited pertain to basic electrical system protection concepts, facility management should be cognizant of them and initiate corrective action when necessary.

Cable Ampacity - The ratings of all protective devices within the scope of this study were examined to see if they conformed to the requirements of NEC Article 240.4 which states that *"Conductors, . . ., shall be protected against overcurrent in accordance with their ampacities . . . "*

Ampacity values for wires with either a 60^{o}C or 75^{o}C thermal rating were used for this evaluation because these wire thermal ratings are stipulated in the UL listing instructions for the terminations of distribution equipment. The termination provisions are based on the use of 60^{o}C rated wire for wire sizes #14 to #1 AWG and 75^{o}C rated wire for wire sizes Nos. 1/0 and greater. Wire with a higher thermal rating may be used but this wire must have a cross-sectional area not less than that of the 60^{o}C or 75^{o}C rated wire in order to comply with the listing instructions. These listing instructions must be followed as required by NEC Article 110.3(B).

The next higher device rating is allowed in the code if the standard ampere rating of the fuse or circuit breaker doesn't correspond to the cable ampacity and if this rating does not exceed 800 amperes. The NEC contains tables of ampacities, which provide standard values for various cable types and voltage ranges. Adjustable trip circuit breaker settings can be considered acceptable if the minimum setting is within the limit imposed by the next largest standard device ampacity. The National Electric Code defines standard ampere ratings for fuses and inverse time circuit breakers in section 240-6 as ". . . 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000 amperes”.

The protective device that protects each of the non conforming circuits should be replaced with one having a rating not greater than that indicated as the maximum device rating <u>or</u> the wire should be replaced with a quantity and size which will provide an ampacity not less than that indicated for the minimum wire size.

The National Electric Code Table 310-16 provides the ampacity of the system's 480V cables.

SIZE	AMPACITY
1/0	150
2/0	175
3/0	200
4/0	230
250	255
300	285
350	310
400	335
500	380
600	420
700	460
750	475
800	490
900	520
1000	545
1250	590
1500	625
1750	650
2000	665

Cable Ampacity for Capacitors is addressed in NEC article 460.8, which states, *"The ampacity of capacitor circuit conductors shall not be less than 135 percent of the rated current of the capacitor."*

Ground fault protection is examined on the 480V system pursuant to NEC articles 230.95 and 215.10. Equipment ground fault protection is required on service and feeder disconnecting means rated 1,000A or more in solidly grounded wye systems with greater than 150V to ground, but not exceeding 600 volts phase-to-phase. Feeder ground fault protection is not required if ground fault protection is installed on the supply side of the feeder, for example, at a main circuit breaker.

The inability of phase overcurrent devices to protect equipment from the damage caused by arcing ground faults is well documented. The arc is resistive and can limit the fault current to levels below the pickup settings of short-time and instantaneous devices. The ground fault may only be isolated through the action of an overload device, which allows the fault to continue for an extended period of time before tripping occurs. This extended time will result in greater damage to equipment than had the ground fault been isolated rapidly. Many instances have been recorded where equipment was literally consumed by an arcing ground fault.

While ground fault protection will greatly reduce the extent of damage that a ground fault arc can cause, the ground fault device may not necessarily operate selectively with phase overcurrent devices downstream. For this reason, ground fault protection on both main and feeder circuit breakers should be contemplated in order to improve selectivity for feeder ground faults. The decision to install ground fault protection on feeder circuit breakers as well as main circuit breakers should consider the following issues:

1. Presence of critical loads on the feeders. Will critical loads experience an outage due to ground faults on other feeders?

2. Rating and type of downstream overcurrent devices. Are downstream phase overcurrent devices capable of sensing ground fault currents within their zone of protection? Is the degree of protection provided by these devices adequate to limit the extent of potential damage to a tolerable level?

3. Main ground fault protection sensitivity. Can the main ground fault device pickup and/or delay be set high enough to allow downstream overcurrent devices to isolate ground fault currents within their protective zone?

The analysis outlined above is beyond the scope of this study. A minimum recommendation would be to have ground fault protection at the main circuit breakers.

Transformer overcurrent protective devices applied at the primary and secondary of transformers were evaluated for compliance with NEC section 450.3. NEC Article 450-3(b)(2) permits the secondary protective device to be set no greater than 125 percent of the transformer rated secondary current when the primary device is not greater than 250 percent of the transformer rated primary current. Note that this article of the NEC *does not* permit the next highest rated device to be applied for the secondary protection when 125% of the rated current does not correspond to a standard rating.

Maximum Continuous Ratings of Fuses and Circuit Breakers
Permitted For Various Transformer Voltage Levels and Impedances
NEC Table 450.3(A)

Transformers with Primaries Over 600V

Location Limitations	Transformer Rated Impedance	Primary Protection		Secondary Side Protection *N2		
				Over 600V		600V or Below
		Maximum Breaker Rating	Maximum Fuse Rating	Maximum Breaker Rating *N4	Maximum Fuse Rating	Maximum Circuit Breaker or Fuse Rating
Any Location	6% & Below	600% *N1	300% *N1	300% *N1	250% *N1	125% *N1
	More than 6% & not more than 10%	400% *N1	300% *N1	250% *N1	225% *N1	125% *N1
Supervised Locations Only *N3	Any	300% *N1	250% *N1	Not Req'd	Not Req'd	Not Req'd
	6% & Below	600%	300%	300% *N5	250% *N5	250% *N5
	More than 6% & not more than 10%	400%	300%	250% *N5	225% *N5	250% *N5

*N = Notes for Table 450.3(A)

1. Where the required fuse rating or circuit breaker setting does not correspond to a standard rating or setting, a higher rating or setting that does not exceed the next higher standard rating or setting shall be permitted.
2. Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device. If both circuit breakers and fuses are used as the overcurrent device, the total of the device ratings shall not exceed that allowed for fuses.
3. A supervised location is a location where conditions of maintenance and supervision ensure that only qualified persons will monitor and service the transformer installation.
4. Electronically actuated fuses that may be set to open at a specific current shall be set in accordance with settings for circuit breakers.
5. A transformer equipped with a coordinated thermal overload protection by the manufacturer shall be permitted to have separate secondary protection omitted.

NEC Table 450.3(B)

Transformers with Primaries 600V and Below

Protection Method	Primary Protection			Secondary Protection *N2	
	Currents of 9 Amperes or More	Currents Less than 9 Amperes	Currents Less than 2 Amperes	Currents of 9 Amperes or More	Currents Less than 9 Amperes
Primary Only	125% *N1	167%	300%	Not Req'd	Not Req'd
Primary & Secondary	250% *N3	250% *N3	250% *N3	125% *N3	167%

*N = Notes for Table 450.3(B)

1. Where 125 percent of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, a higher rating that does not exceed the next higher standard rating shall be permitted.
2. Where secondary overcurrent protection is required, the secondary overcurrent device shall be permitted to consist of not more than six circuit breakers or six sets of fuses grouped in one location. Where multiple overcurrent devices are utilized, the total of all the device ratings shall not exceed the allowed value of a single overcurrent device. If both breakers and fuses are utilized as the overcurrent device, the total of the device ratings shall not exceed that allowed for fuses.
3. A transformer equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current, shall be permitted to have primary overcurrent protection rated or set at a current value that is not more than six times the rated current of the transformer for transformers having not more than 6 percent and not more than four times the rated current of the transformer for transformers having more than 6 percent but not more than 10 percent impedance.

Conductors that supply motor loads are subject to special requirements found in Article 430 of the NEC. First, it should be noted that NEC Table 430.150 shall be utilized for the full load current values applied to cable ampacity calculations for three-phase motors as specified in Article 430.6. The table supplies full load current values for motors rated up to 200HP. Current values for motors rated greater than 200HP can be interpolated from the table data.

References to motor full load current ratings in this report, when related to conductor ampacity, pertain to the values found in the NEC tables. Motor branch conductors supplying a single motor must have an ampacity greater or equal to 125 percent of the motor full load current rating (Article 430.24). The ampacity of both branch and feeder conductors which supply several motors must have a minimum ampacity greater or equal to the sum of the full load currents of the connected motors plus 25 percent of the full load current rating of the highest rated motor. These requirements must be applied when motors are operated simultaneously and continuously. However, special consideration can be granted from the authority having jurisdiction to these requirements when it can be shown that on-duty cycle, demand factor is less than 100 percent, operational procedures, production demands or nature of the work is such that not all motors are running at the same time and reduce the conductor heating sufficiently to allow use of a smaller conductor size (Article 430.26). In this report, motors are assumed to be run on a continuous basis unless stated otherwise.

Procedures

The coordination study generally begins at the Main Service Breaker. Settings were chosen with the goal of providing the best coordination that was possible with the largest downstream fixed-setting protective device (such as a transformer breaker). The study then proceeds by coordinating each of the feeder and sub-panel breakers. Time-current curves were used to determine the settings that provided optimum coordination. This report contains those time-current curves that were deemed to contain essential information.

The following is a tested, generally accepted philosophy for selecting and setting protective devices:

1. A feeder "first-line" or "primary" protective device will remove fault current as quickly as possible.
2. If the feeder primary protection fails, a "back-up" protective device will remove the fault. An upstream device that acts as the primary device in its zone usually provides the back-up function. Therefore, time-current coordination is required between the feeder primary and back-up protective devices.

The protective device settings are individually chosen to accommodate circuit parameters. The criteria used in determining the recommended feeder protective device settings are:

1. System or feeder circuit full-load current.
2. Allowance for coordination with the largest downstream protective device set to the highest pickup and time delay including substation secondary circuit protective devices.
3. Transformer protection in compliance with American National Standards Institute (ANSI) and National Electrical Code (NEC) requirements.
4. Avoidance of nuisance tripping due to transformer magnetizing inrush currents or motor inrush currents.
5. Short circuit for faults occurring in the protected zone of the system, including faults on transformer secondaries.
6. Protection of cables per NEC requirements and published heating limits.

Included in the report are protective device one-line diagrams which functionally depict connections of protective devices to instrument transformers (current transformers, potential transformers).

Calibration and Testing of Protective Devices

The time-current relationships between protective devices as established in this report require that the individual relay operating characteristics do not depart appreciably from those shown on the published time-current curves from the manufacturer. The specified settings will provide operation of the devices essentially as shown. However, device tolerance and the difficulty in obtaining exact field settings may result in deviations from the specified operating times. Therefore, it is recommended that the device settings be calibrated by field tests to insure the desired response.

Satisfactory device coordination depends on operation of the protective devices when required, even though they may be inactive for long periods of time. To assure continued proper device action, it is essential the devices be calibrated and checked at regular intervals.

Low Voltage Cable Protection
Article 240.3 of the National Electric Code states that *"Conductors, . . . , shall be protected against overcurrent in accordance with their ampacities . . . "* The next higher standard overcurrent device rating (above the ampacity of the conductors being protected) is allowed in the code with some conditions if the standard rating of the fuse or circuit breaker doesn't correspond to the cable ampacity (below 800 amperes). NEC section 220.10(B) precludes setting an overcurrent protective device above its ampere rating in most situations.

System Medium Voltage Relay Settings
The medium voltage system relay settings are given in the *Relay Settings Table*.

One protection philosophy followed in this study in most cases is the avoidance of 0.5 relay time dial settings with standard non-static overcurrent relays. This is because experience has shown that nuisance tripping can be caused in this situation due to simple vibration. As much as possible, 0.75 is the lowest time dial setting used.

Low Voltage Circuit Breaker Settings
The low voltage circuit breaker device settings are provided in the *Adjustable Breaker Settings Table*. The protection and coordination for many of these circuit breakers becomes highly redundant, and many settings can be derived from a single curve.

As the table may indicate, some of the long time band settings may be set higher than minimum to allow coordination with downstream circuit breakers or fuses. In most cases the long time pickup is set for cable protection. Short time trip settings are chosen for close coordination with downstream devices, while the instantaneous trip settings are set at their highest value to allow maximum selectivity with upstream coordination. Also taken into account is the fault current available at the end of a feeder. This is to assure that a breaker operates when subjected to fault current levels.

ANSI STANDARD DEVICE FUNCTION NUMBERS

Dev. No.	Function
1.	Master Element
2.	Time-delay Starting or Closing Relay
3.	Checking or Interlocking Relay
4.	Master Contactor
5.	Stopping Device
6.	Starting Circuit Breaker
7.	Anode Circuit Breaker
8.	Control-Power Disconnecting Device
9.	Reversing Device
10.	Unit Sequence Switch
11.	Reserved for Future Application
12.	Over-speed Device
13.	Synchronous-speed Device
14.	Under-speed Device
15.	Speed or Frequency-Matching Device
16.	Reserved for Future Application
17.	Shunting or Discharge Switch
18.	Accelerating or Decelerating Device
19.	Starting-to-Running Transition Contactor
20.	Electrically Operated Valve
21.	Distance Relay
22.	Equalizer Circuit Breaker
23.	Temperature Control Device
24.	Reserved for Future Application
25.	Synchronizing or Synchronism-Check Device
26.	Apparatus Thermal Device
27.	Undervoltage Relay
28.	Flame Detector
29.	Isolating Contactor
30.	Annunciator Relay
31.	Separate Excitation Device
32.	Directional Power Relay
33.	Position Switch
34.	Master Sequence Device
35.	Brush-Operating or Slip-Ring Short-Circuiting Device
36.	Polarity or Polarizing Voltage Device
37.	Undercurrent or Underpower Relay
38.	Bearing Protective Device
39.	Mechanical-Condition Monitor
40.	Field Relay
41.	Field Circuit Breaker
42.	Running Circuit Breaker
43.	Manual Transfer or Selector Device
44.	Unit Sequence Starting Relay
45.	Atmospheric Condition Monitor
46.	Reverse-Phase or Phase-Balance Current Relay
47.	Phase-Sequence Voltage Relay
48.	Incomplete Sequence Relay
49.	Machine or Transformer Thermal Relay
50.	Instantaneous Overcurrent or Rate-of-Rise Relay

Dev. No.	Function
51.	AC Time Overcurrent Relay
52.	AC Circuit Breaker
53.	Exciter of DC Generator Relay
54.	Reserved for Future Application
55.	Power Factor Relay
56.	Field-Application Relay
57.	Short-Circuiting or Grounding Device
58.	Rectification Failure Relay
59.	Overvoltage Relay
60.	Voltage or Current Balance Relay
61.	Reserved for Future Application
62.	Time-Delay Stopping or Opening Relay
63.	Pressure Switch
64.	Ground Protective Relay
65.	Governor
66.	Notching or Jogging Device
67.	AC Directional Overcurrent Relay
68.	Blocking Relay
69.	Permissive Control Device
70.	Rheostat
71.	Level Switch
72.	DC Circuit Breaker
73.	Load-Resistor Contactor
74.	Alarm Relay
75.	Position Changing Mechanism
76.	DC Overcurrent Relay
77.	Pulse Transmitter
78.	Phase Angle Measuring or Out-of-Step Protective Relay
79.	AC Reclosing Relay
80.	Flow Switch
81.	Frequency Relay
82.	DC Reclosing Relay
83.	Automatic Selective Control or Transfer Relay
84.	Operating Mechanism
85.	Carrier or Pilot-Wire Receiver Relay
86.	Locking-Out Relay
87.	Differential Protective Relay
88.	Auxiliary Motor or Motor Generator
89.	Line Switch
90.	Regulating Device
91.	Voltage Directional Relay
92.	Voltage and Power Directional Relay
93.	Field-Changing Contactor
94.	Tripping or Trip-Free Relay
95.)	
96.)	Used only for specific applications on individual
97.)	installations where none of the assigned numbered
98.)	functions from 1 to 94 are suitable.
99.)	

General Discussion of Protective Devices

The elements that make up a protected system include relays, direct-acting trip devices, and fuses. Low-voltage power circuit breakers and insulated-case circuit breakers can be adjusted within certain limits to meet protection and coordination requirements. In medium and high-voltage systems, relays are used almost exclusively in the design of a flexible and coordinated protective system.

A brief description of some common relay types used in power distribution systems follows. Appropriate instruction books should be consulted to obtain further information concerning equipment details and their application.

Time-Overcurrent Relays (Device 51) - These relays operate on the electromagnetic induction principle and are available with several time-current operating characteristics. This flexibility makes it possible to select operating characteristics in close harmony with the protective requirements of a particular system component. These relays are non-directional in their operation and are used for both phase and ground fault overcurrent protection of transformers and distribution circuits. Special types are available for motor and generator protection.

The theoretical minimum current at which the relay will operate is called the *pickup current*, which is adjustable within a specified range by changing the *ampere tap* plug. Because of extremely low torques at low-current magnitude, electromechanical relays cannot generally be expected to operate predictably for currents less than 1.5 times the ampere tap setting. This accounts for the termination of the published time operating characteristics at this current level.

Generally, the time delay can be changed by means of a continuously adjustable time dial marked 0 to 10 or 0 to 11. Time-dial markings are arbitrary reference points and are not related to the actual time delay in seconds.

On time-current plots, relay operating characteristics are extended to the maximum short-circuit current value to which a relay is expected to respond. If the overcurrent relay is equipped with an instantaneous attachment (Device 50), then the curve will be terminated at the intersection with the instantaneous relay characteristic.

Overcurrent relays intended for phase fault protection are denoted as 51. Residually connected ground fault relays carry the designation 51N while ground fault relays connected to current transformers in the neutral of a transformer or generator are designated as 51G.

Time overcurrent relays employing electronic circuitry are also available. While these relays have different operating principles from their electromechanical counterparts, the general application procedures described still apply.

Instantaneous Overcurrent Relays (Device 50) - Instantaneous relays have extremely fast operating times (about one cycle). They are essential for fast clearing of extremely high fault currents to reduce burning damage and the possibility of unstable operation of rotating machinery.

However, instantaneous relays cannot always be used when selectivity is desired. Since they cannot be made selective with other instantaneous relays, they are generally only used as the last downstream relay of a series of protective devices which respond to essentially the same magnitude of short-circuit current. This may be a branch-circuit protector, such as a motor starter, or a transformer primary protector.

Whenever there is a large impedance in the circuit (such as a current-limiting reactor or a transformer) the fault current level on the load side may differ significantly from that on the source side. In such cases, the instantaneous relay on the source side of the impedance may be able to be set above the current that would flow to a fault on the load side.

Selectivity between instantaneous relays and fuses for fault clearing times of less than 0.1 second cannot be evaluated on a time-current basis. Since sufficient data are not available to verify selectivity, extreme caution should be exercised in predicting coordination on the basis of the time current characteristics of these devices.

Instantaneous relays may be either self-contained or provided as an attachment to a time-overcurrent relay. Many instantaneous relays operate on the electromagnetic attraction principle. These relays will operate equally well on dc and ac currents and the settings determined for them must recognize the possibility of asymmetry in the fault current. Induction cup type instantaneous relays are available for special applications.

Ground instantaneous relays are given designation suffixes in the same manner as ground time overcurrent relays.

Ground Relays (Devices 50GS and 51GS) - A sensitive ground-fault relay is used to take full advantage of a resistance-grounded system. This ground-fault relay is connected to a low-ratio, window-type current transformer encompassing the three-phase conductors. A matched combination is commonly referred to as a ground sensor. Both time-overcurrent and instantaneous ground sensors can be used (Devices 51GS and 50GS, respectively) to obtain selectivity.

The low-burden capability of window-type transformers introduces a ratio error which is taken into account by the use of operating curves applicable to the ground sensor package being used; that is, the relay-CT combination. These curves may be obtained only by test and are available from the manufacturer. Note that directional ground overcurrent relays should never be connected to low ratio window-type current transformers.

The ground sensor is not responsive to positive and negative sequence load currents but is sensitive to zero sequence (ground fault) currents. Hence, the current transformer ratio is not governed by the anticipated load currents. A 50/5 current transformer ratio is generally used.

Differential Relays (Devices 87G, 87T, 87B and 87L) - Differential relays are employed to permit fast and sensitive protection for phase and ground faults in a bus (87B), a generator (87G), a transformer (87T), or a line (87L). Their use will not only reduce fault point burning damage, but will also improve the ability of rotating machines in the system to return to a stable, steady state mode of operation following a disturbance in the differential zone.

Differential relays are connected to two or more sets of current transformers located at the perimeters of the zone to be protected. Current transformers ideally should have identical characteristics so that through currents will not result in false operation of the differential relays. To allow for normal current transformer tolerances, differential relays are designed to be insensitive to small error currents.

Transformer differential relays are normally designed to provide restraint for harmonic currents predominant in transformer magnetizing inrush currents that are sensed by the transformer source-side current transformers. An adjustable percentage slope adjustment permits de-sensitizing the relay to prevent misoperation for a through fault due to current transformer ratio errors. Ratio tap adjustments are provided to match as nearly as possible the secondary currents in the primary and secondary current transformers.

COORDINATION STUDY ANALYSIS

Discussion and Recommendations

The coordination study analysis is provided below.

- All Feeder Breakers should be set and tested at the recommended settings.
- All low-voltage breakers should be set and tested at their recommended settings for proper coordination with upstream breakers and for proper protection of equipment.

ARC FLASH STUDY INTRODUCTION

Introduction

The purpose of an arc flash hazard analysis is to determine arc flash boundary values and appropriate Personal Protective Equipment (PPE) based on coordinated circuit protective devices within an electrical distribution system. Protective device settings are selected to provide a reasonable compromise between the level of required PPE and the desired system operability, based on a thorough engineering evaluation, between the often-conflicting goals of maximum protection and greatest service continuity. Judgments were made as to the best balance between these factors.

The Arc Flash Study's methods and recommendations are in conformance with the NFPA-70E-2004 and NEC-1584. A general explanation of the methods used for this portion of the study can be found in the section entitled *Procedures.*

Compliance with Codes and Standards

The results of the study include the calculated Arc-Flash Boundary and the calculated Incident Energy (in cal/cm2) at key system points within the scope of the short circuit study. The Incident Energy will be shown with its related Protective Clothing System as found in NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces-latest edition. Arc-Flash calculations are made using ESA's EasyPower 7.0 software equations (IEEE Std 1584-2002, IEEE Guide for Performing Arc-Flash Hazard Calculations).

The following discussion addresses the study's compliance with the NFPA-70E Standards for Safety in the Workplace, and IEEE-1584's methodologies for calculating Arc Flash incident energy levels. Results of this study are in conformance with Tables 130.7(C)(9a), (10), and (11), Hazard Risk Category, the Protective Clothing and Personal Protective Equipment Matrix, and Protective Clothing Characteristics.

Procedures

The Arc Flash Hazard analysis is carried out in the *short circuit focus portion* of the analysis software, and the methodology for calculating incident energy levels is selectable between IEEE's 1584, NFPA-70E, and/or ESA's customizable calculation methods.

IEEE-1584 recommends using two scenarios when detemining the worst case scenario for incident energy levels – 100% of estimated fault current, and 85% of estimated fault current. Accurate arcing times must be determined since incident energy levels are more sensitive to arcing time than arcing current as a result of the inverse-time characteristics of the typical over-current protective device – arcing time is typically longer for smaller currents and shorter for larger currents. Therefore, both current values are evaluated, and the worst case scenario is reported.

The NFPA-70E specifies two types of flash boundaries; those were the arcing time is less than 0.1 second, the boundary is at a distance where the energy level is less than or equal to 1.5cal/cm^2, and for arcing times greater than 0.1 second, the boundary is at a distance where the energy level is less than or equal to 1.2cal/cm^2.

The calculations shown as part of this report are a result of Bus Hazards excluding the protective effects of a main (if so equiped) on the bus under evaluation: This option yields the results for fault on the bus bar excluding the tripping effect of the main breaker. This option of output is applicable to energized work on the line side of the main breaker of the bus. The upstream trip device is used to calculate the arcing time.

Arc Flash Analysis is not performed on buses at 120/208V located after secondary sides of transformers rated 125kVA or less per IEEE 1584. The reasoning behind excluding buses at 120/208V beyond transformers less than 125kVA is that it is highly unlikely for a fault to be sustained on such devices for an extended length of time, and the calculations typically result in unrealistic incident energy levels.

ARC FLASH STUDY ANALYSIS

Basis of Analysis

The Arc Flash Hazard analysis was performed based on the short circuit study and coordination analysis that resulted as part of the overall power system study. Fault current values are based on Nevada Power Company transformer data tables, and breaker coordination setting values were adjusted to result in the lowest possible PPE level, yet the greatest ability for breakers to withstand inrush current from motors and transformers.

Arc flash data is not calculated for buses upstream of the utility main disconnect because these values are dependent on utility fuse type and rating values which are not under the customer's control for sizing and maintenance purposes.

Results of Analysis

Results of the Arc Flash Analysis are summarized in tables found in the Appendix. Arc Flash results are greater for Ground Fault conditions, but may be limited based on the fusing implemented by the utility. It is best to implement PPE based on the highest value determined from this study.

APPENDIX

Breaker Settings

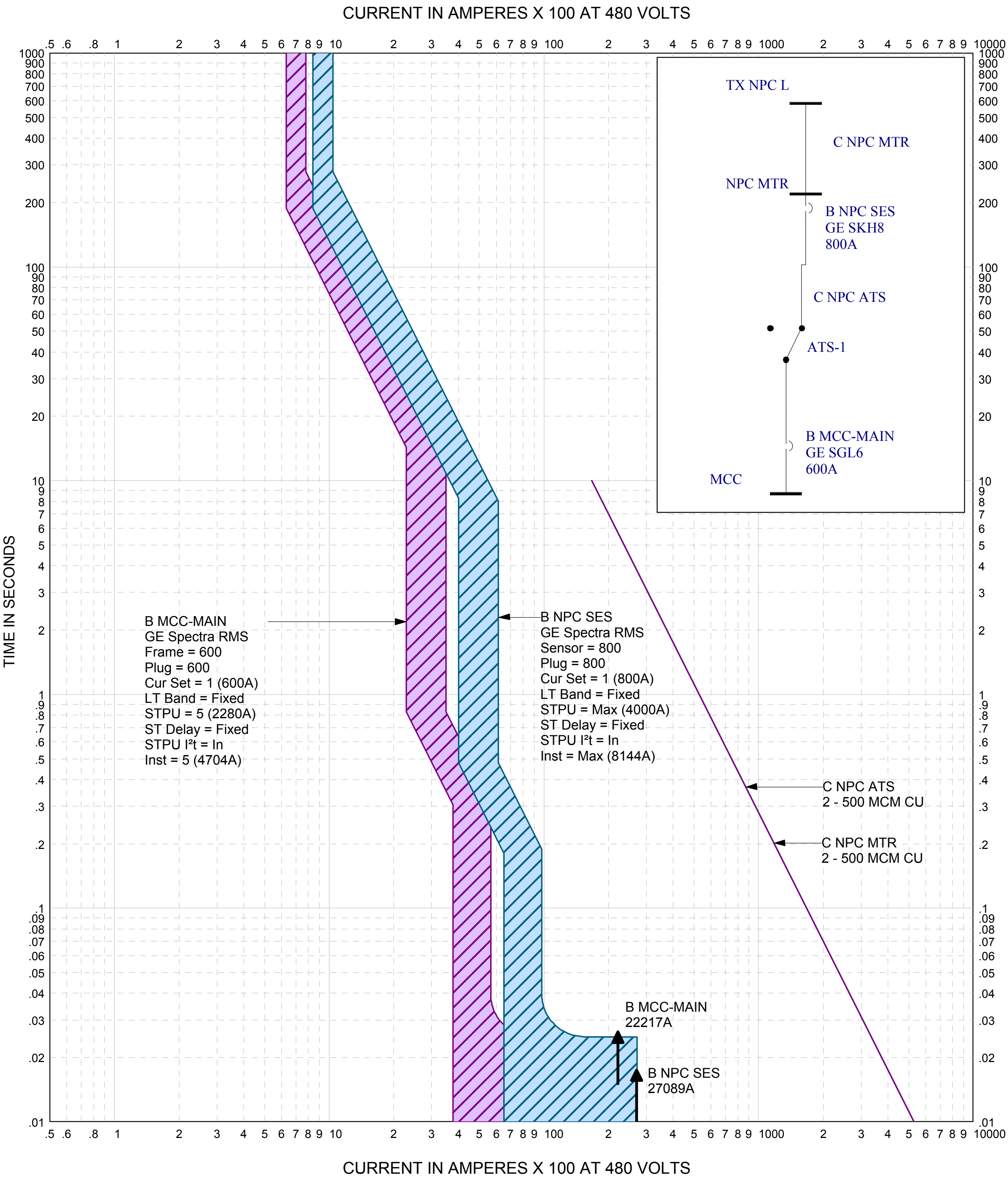
Adjustable Breaker Settings
2/6/2006

Adjustable Breaker Name	Manufacturer	Type	Style	Sensor/ Frame	Plug/ Tap	LTPU				LT Delay		STPU					Inst			Ground Trip			
						Name	Setting	Mult	Trip (A)	Name	Band	Name	Setting	Trip (A)	Band	I2t	Setting	Override	Trip (A)	Pickup	Trip (A)	Delay	I2t
B NPC SES	GE	Spectra RMS	MCCB SK	800	800	LT Pickup	1		800	LT Delay	Fixed	ST Pickup	Max	4000	Fixed	In	Max	Pickup	8144				Out
B MCC-MAIN	GE	Spectra RMS	MCCB SG	600	600	LT Pickup	1	1	600	LT Delay	Fixed	ST Pickup	Max	3000	Fixed	In	Max	Pickup	6072				Out
B H1	GE	Spectra RMS	MCCB SF	250	200	LT Pickup	1		200	LT Delay	Fixed	ST Pickup	Max	1000	Fixed	In	Max	Pickup	2000				Out
B T-L	GE	Spectra RMS	MCCB SF	250	200	LT Pickup	1		200	LT Delay	Fixed	ST Pickup	Max	1000	Fixed	In	Max	Pickup	2000				Out
B L3-FDR						LTPU				LT Band		STPU						Pickup					
B PKG BIOFLTR	GE	Spectra RMS	MCCB SE	100A (100AT)	100	LT Pickup	1	1	100	LT Delay	Fixed	ST Pickup	Max	660	Fixed	In	Max	Pickup	1250				Out
B LIFT PMP1	GE	Spectra RMS	MCCB SE	100A (100AT)	100	LT Pickup	1	1	100	LT Delay	Fixed	ST Pickup	Max	660	Fixed	In	Max	Pickup	1250				Out
B LIFT PMP2	GE	Spectra RMS	MCCB SE	100A (100AT)	100	LT Pickup	1	1	100	LT Delay	Fixed	ST Pickup	Max	660	Fixed	In	Max	Pickup	1250				Out
B LIFT PMP3	GE	Spectra RMS	MCCB SE	100A (100AT)	100	LT Pickup	1	1	100	LT Delay	Fixed	ST Pickup	Max	660	Fixed	In	Max	Pickup	1250				Out
B H1-MAIN	GE	Spectra RMS	MCCB SF	250	200	LT Pickup	1		200	LT Delay	Fixed	ST Pickup	Max	1000	Fixed	In	Max	Pickup	2000				Out

Thermal Magnetic Breakers
2/6/2006

Thermal Magnetic Breaker	Manufacturer	Type	Style	Frame	Trip	Instantaneous	
						Setting	Trip (A)
B H1-FDR	GE	E150	TEY - 25kA	100A (15A)	15		
B L3	GE	Q Line	THHQB	100A (15-50AT)	50		
B L1-MAIN	GE	Q Line	THQD	225A(100-225AT)	200		
B L2-MAIN	GE	Q Line	THQD	225A(100-225AT)	100		
B L1-FDR	GE	Q Line	THHQB	100A (15-50AT)	15		

Time Current Curves

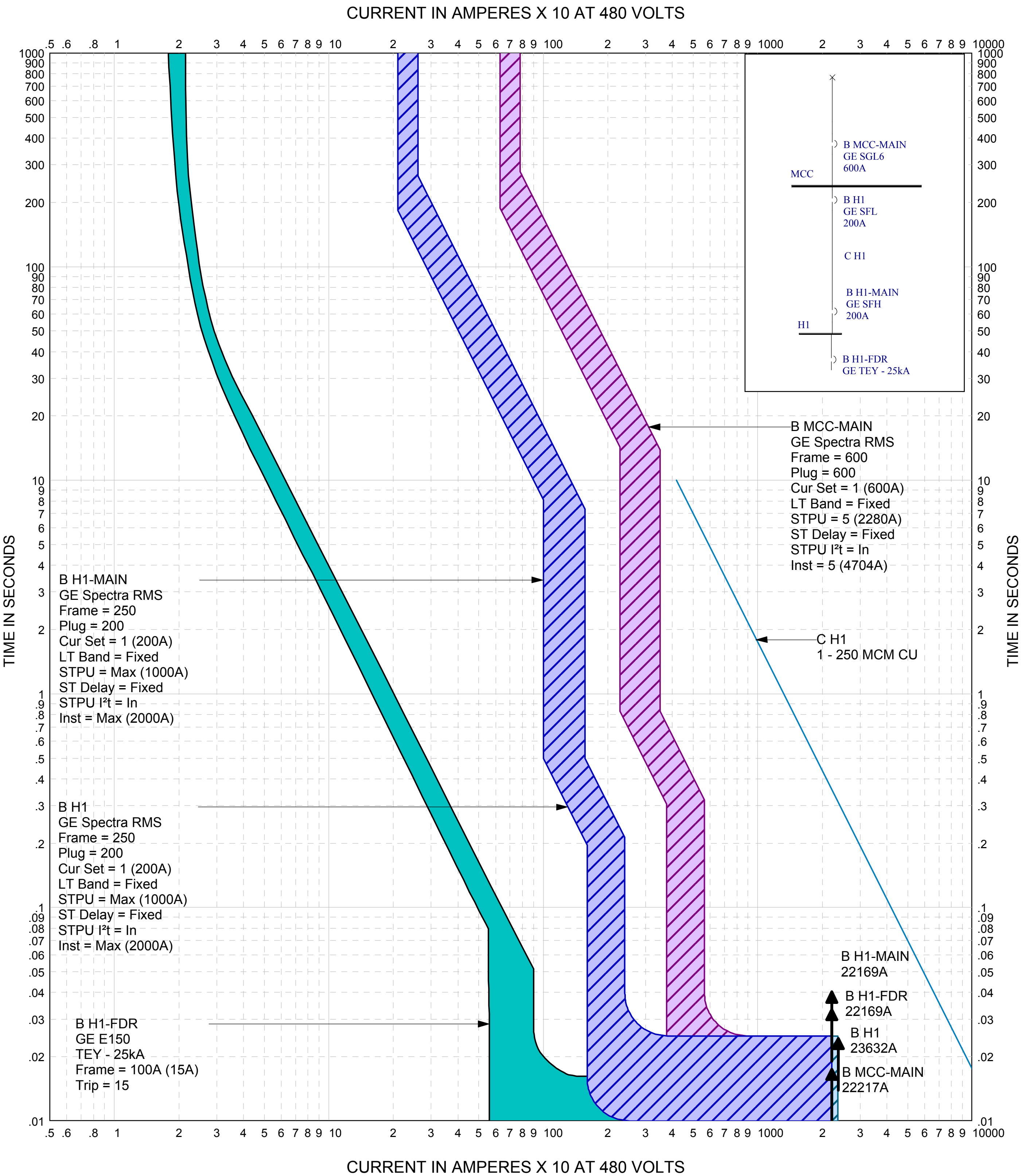


PQTSi	***EasyPower*** ® **TIME-CURRENT CURVES**	SVC Ent - MCC Main

PEBBLE LIFT STATION

Breaker Settings: Service Entrance breaker, MCC-Main

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0

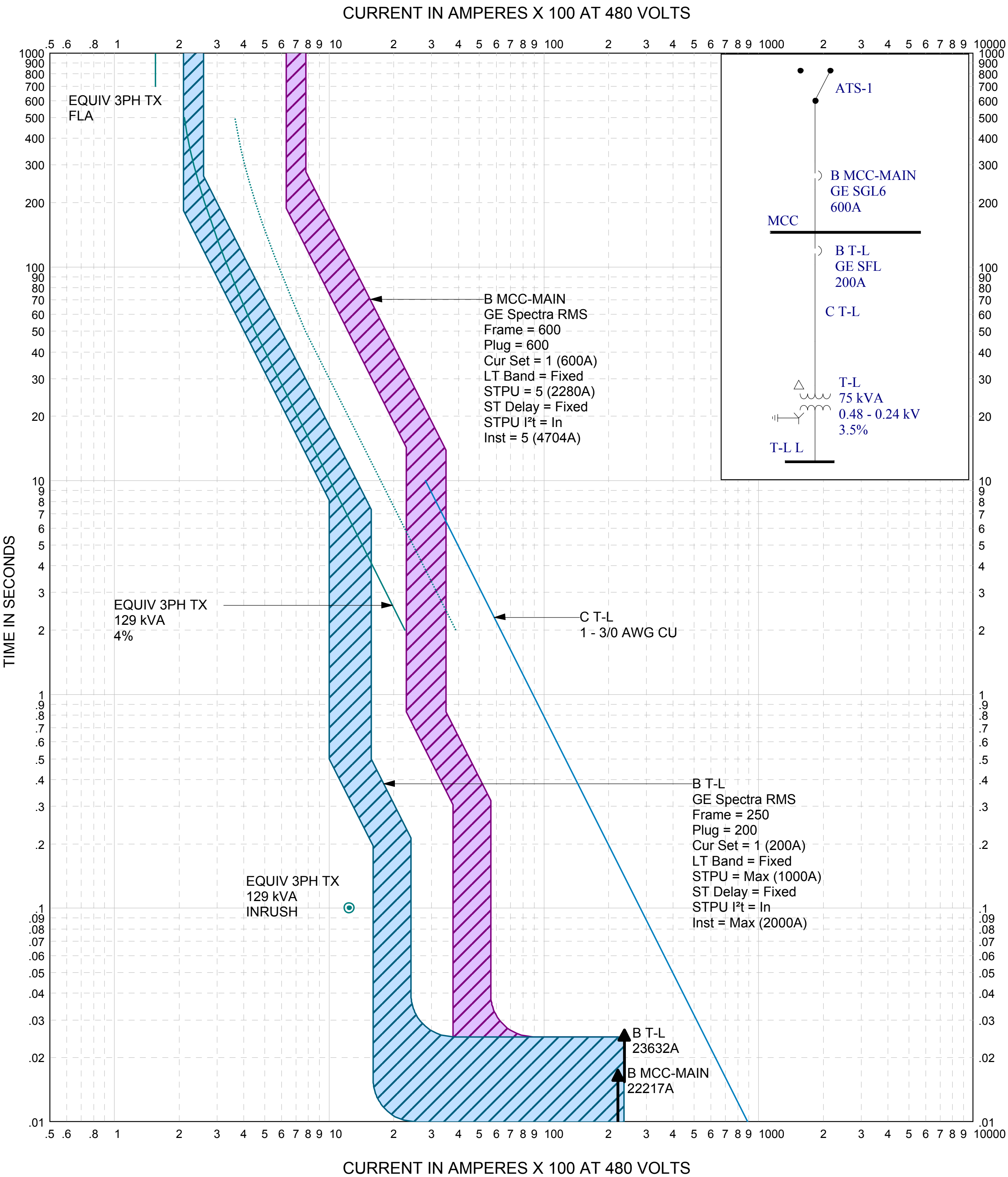


PQTSi	***EasyPower*** ® **TIME-CURRENT CURVES**	Panel H1

PEBBLE LIFT STATION

Breaker Settings: MCC-Main, Feeder H1, H1-Main, H1-Branch

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0

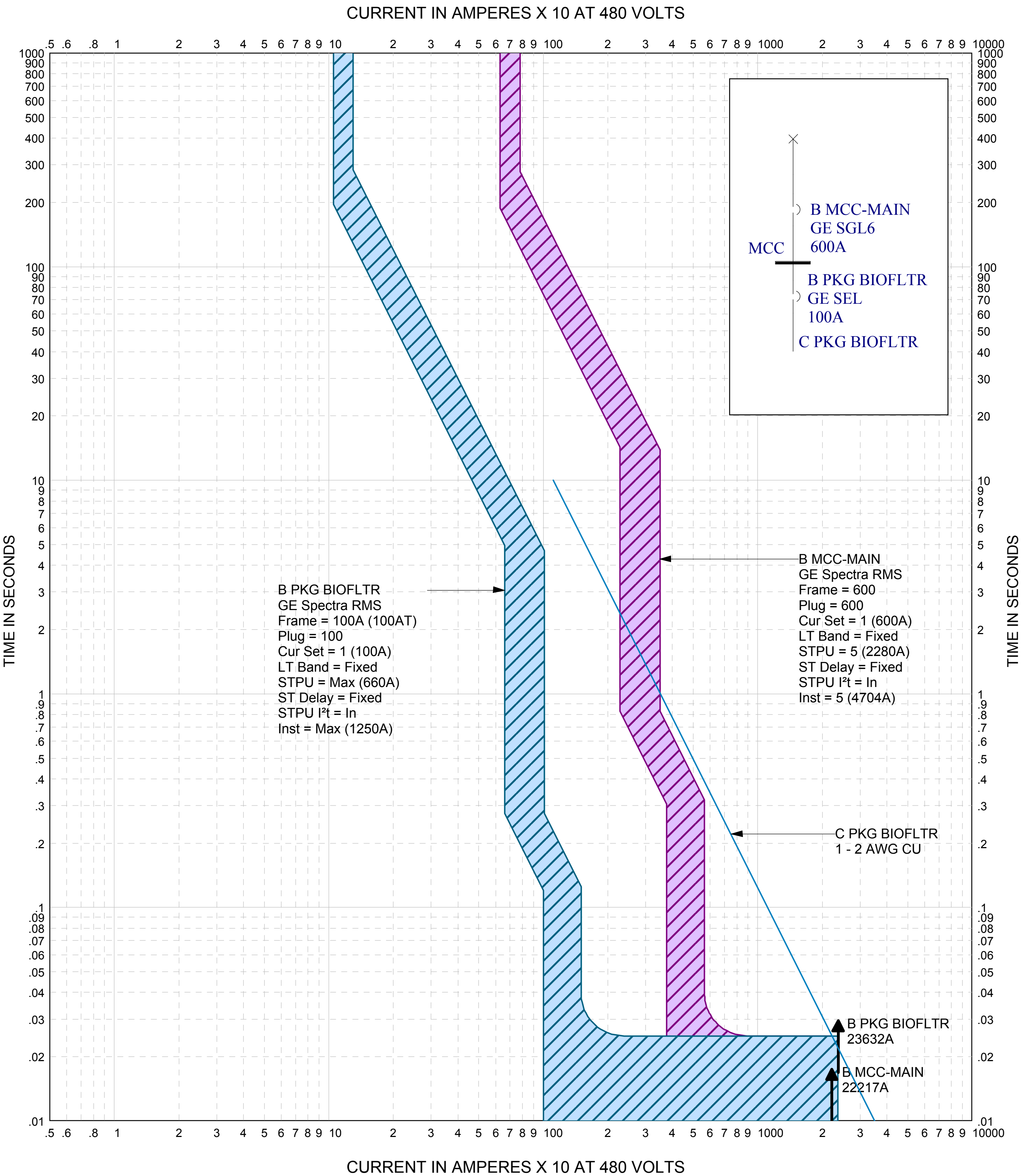


PQTSi	***EasyPower*** ® **TIME-CURRENT CURVES**	Transformer T-L

PEBBLE LIFT STATION

Breaker Settings: MCC-Main, Feeder T-L

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0



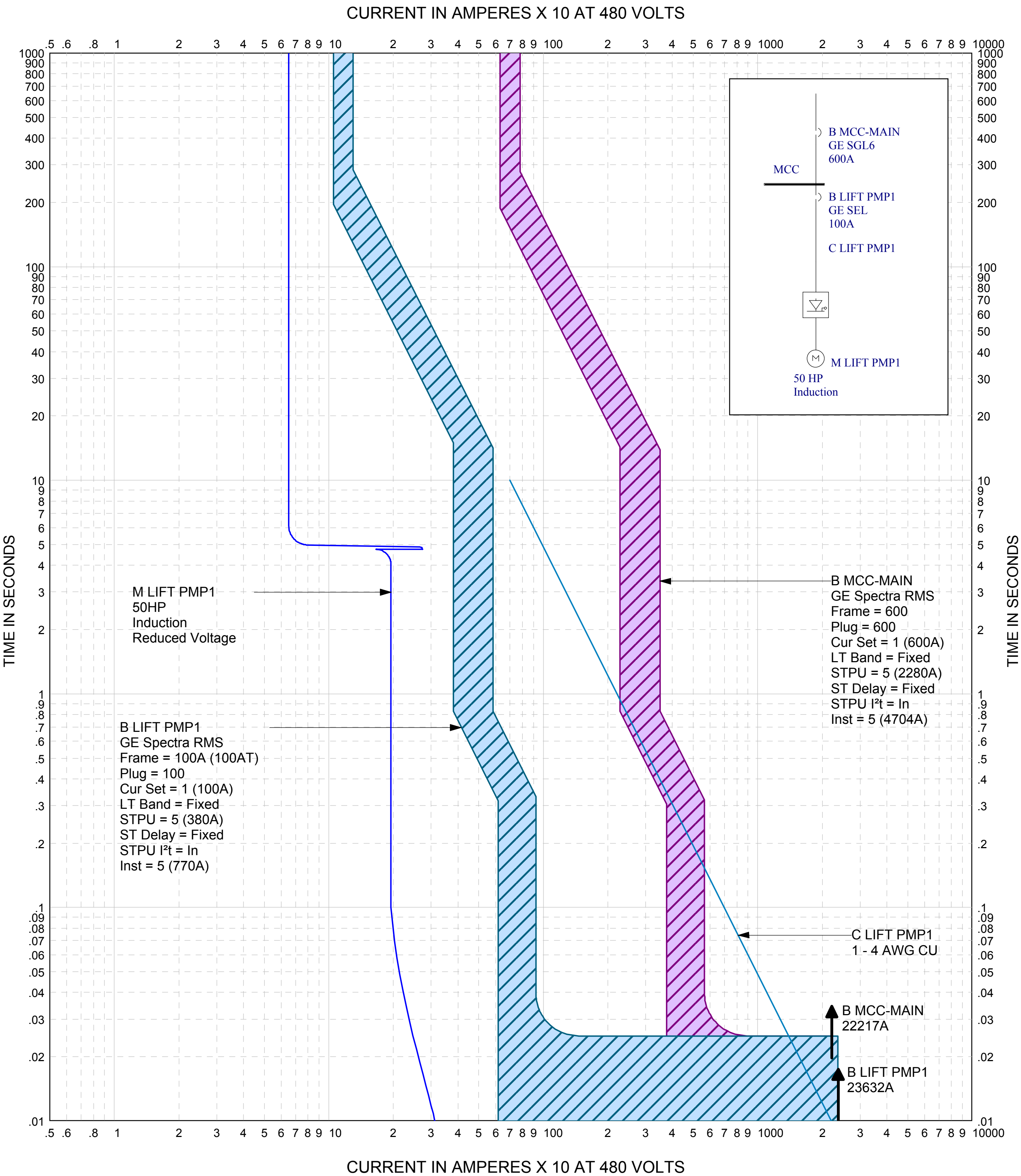
PQTSi	***EasyPower*** ® **TIME-CURRENT CURVES**	Pkg Biofilter

PEBBLE LIFT STATION

Breaker Settings: MCC-Main, Feeder Pkg BioFilter

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0

PEBBLE LS

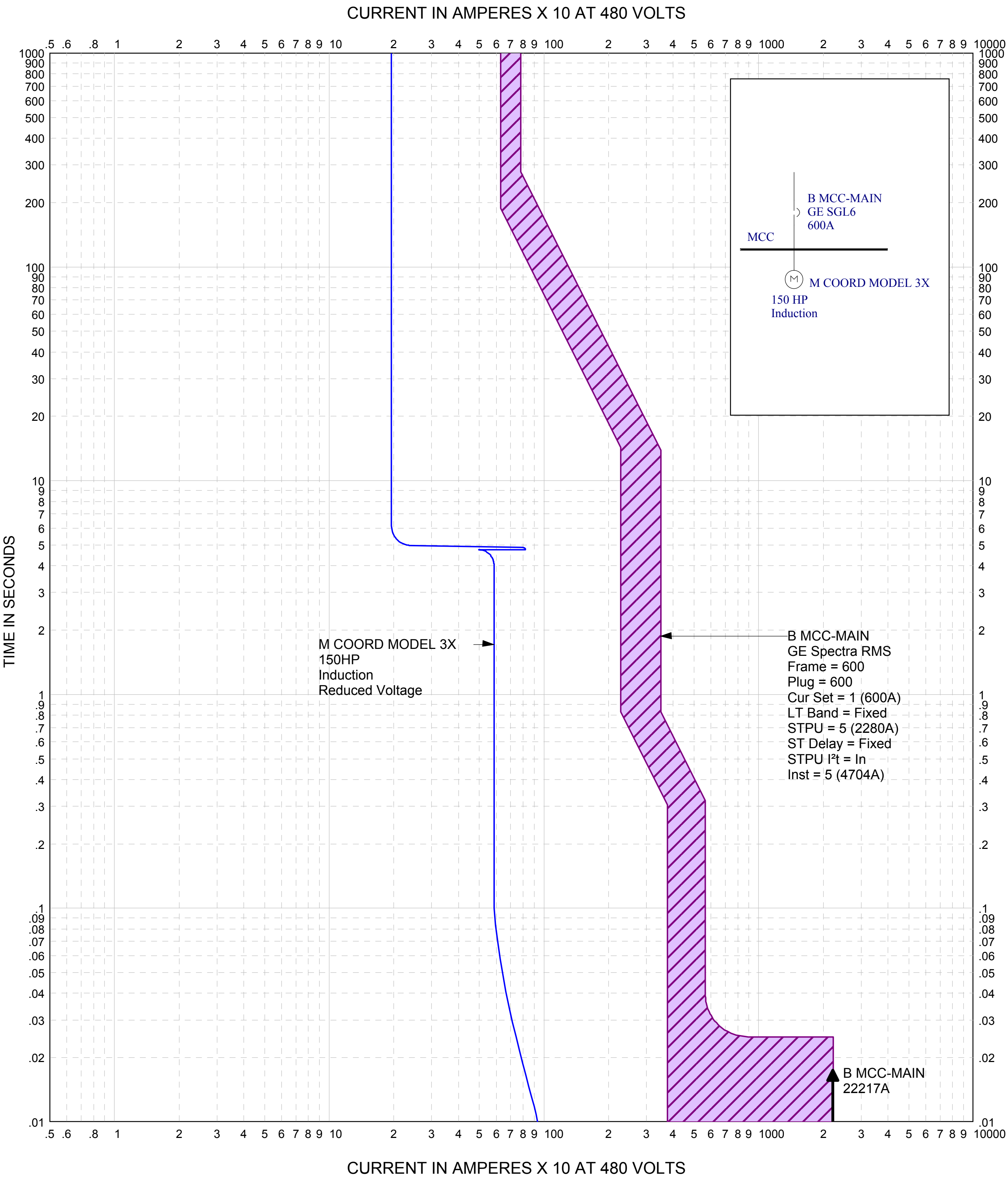


PQTSi	***EasyPower*** ® **TIME-CURRENT CURVES**	Lift Pump 1

PEBBLE LIFT STATION

Breaker Settings: MCC-Main, Feeder Lift Pump 1
(typical for Pump 2 & 3)

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0

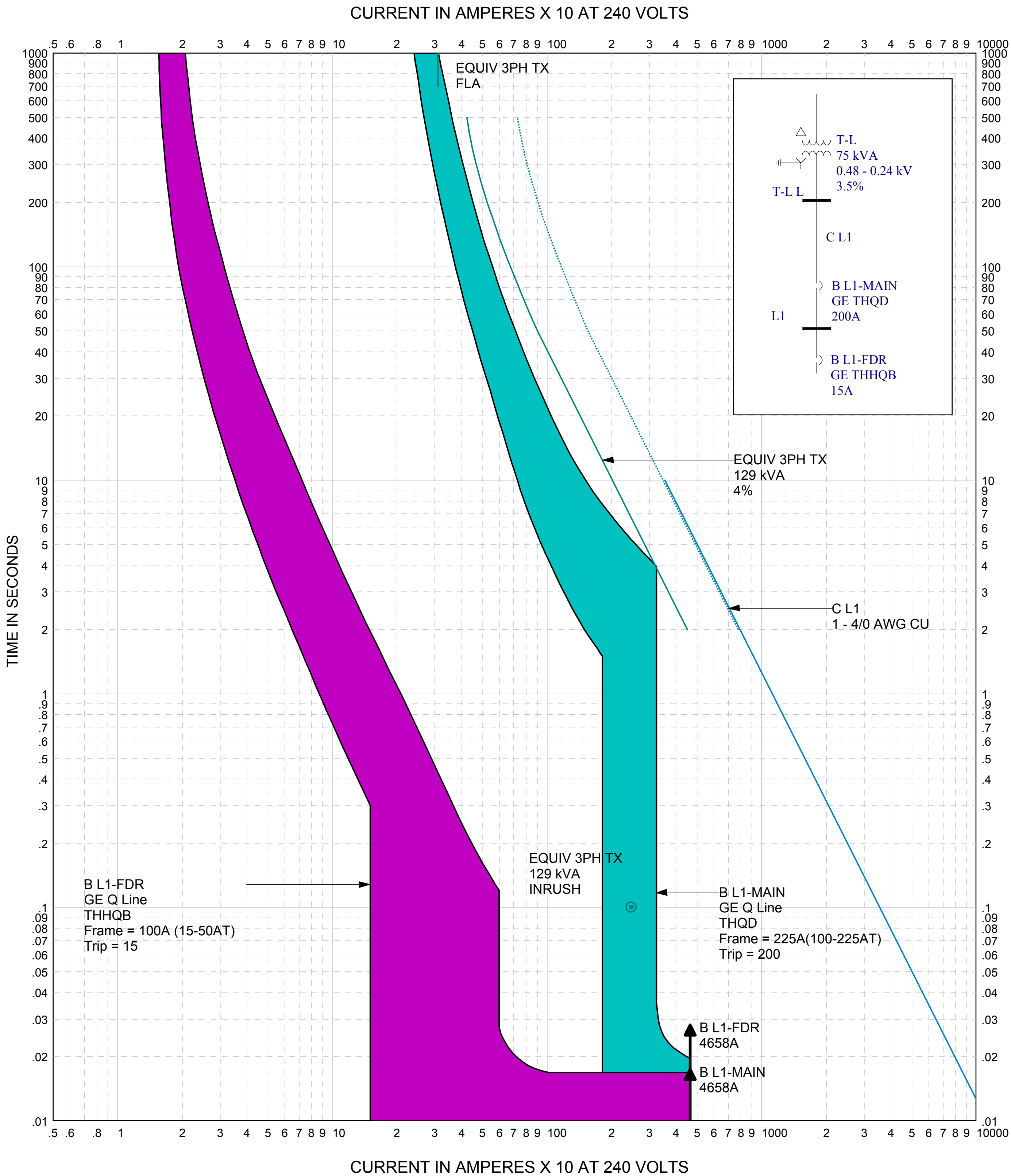


PQTSi	***EasyPower*** ® **TIME-CURRENT CURVES**	3-Pumps

PEBBLE LIFT STATION

Breaker Settings: MCC-Main with 3 Pumps

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0

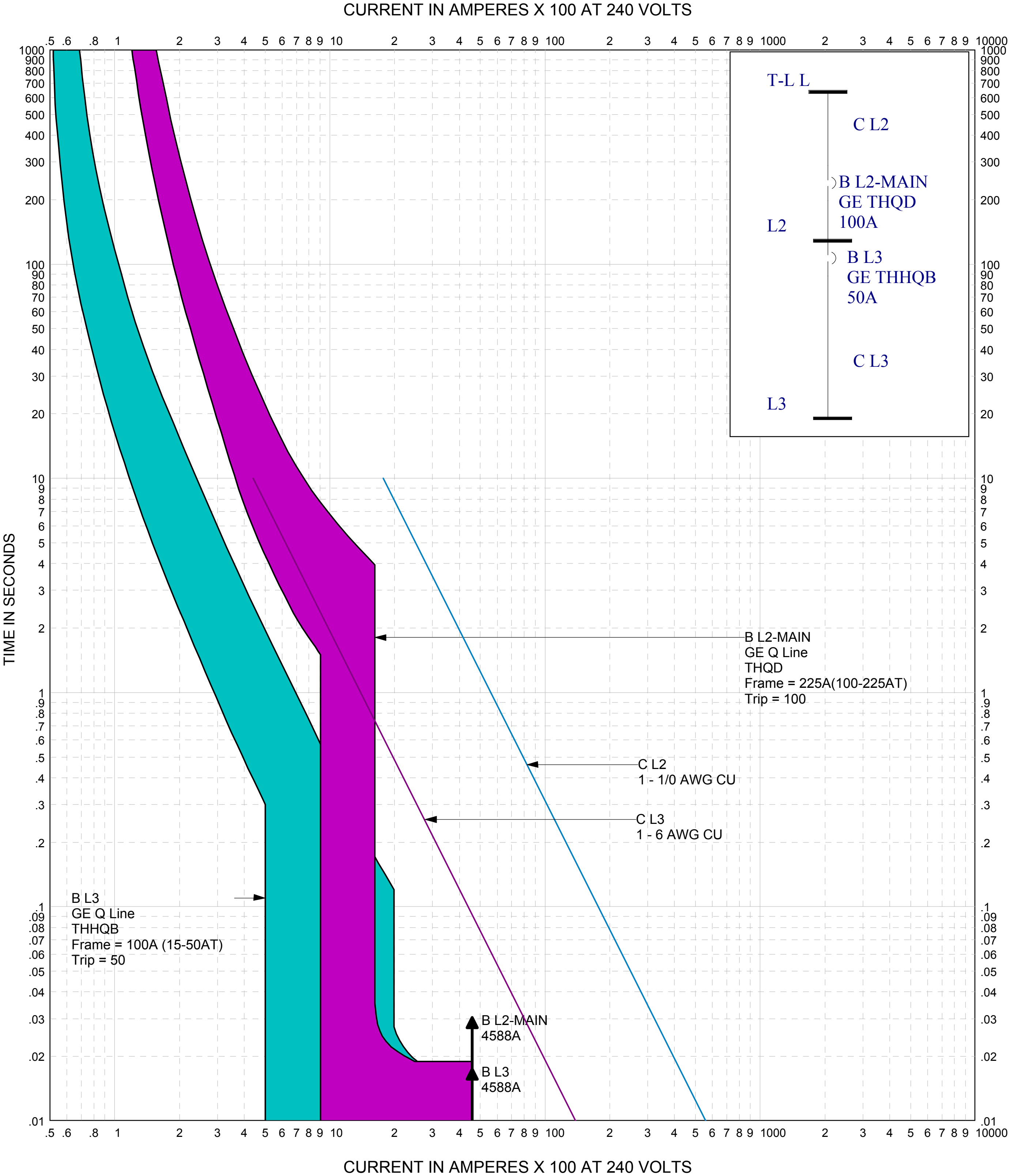


PQTSi	***EasyPower*** ® **TIME-CURRENT CURVES**	Panel L1

PEBBLE LIFT STATION

Breaker Settings: Panel L1-Main, Paenl L1-Branch

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0



PQTSi	*EasyPower* ® **TIME-CURRENT CURVES**	Panel L2

PEBBLE LIFT STATION

Breaker Settings: Panel L2-Main, L2 branch

FAULT: Phase
DATE: Feb 06, 2006
BY: Joe Dietrich
REVISION: 0

Arc Flash Hazard Report

Arc Flash Hazard Report

Arc Flash is Valid only with settings as per Coordination Study - Breaker Tables dated 02-06-2006

Arc Fault Bus Name	Arc fault Bus kV	Upstream Trip Device Name	Equipment Type	Arc Gap (mm)	Bolted Fault (kA)	Est. Arc Fault (kA)	Trip Time (sec)	Opening Time (Sec)	Arc Time (Sec)	Est. Arc Flash Boundary	Working Dist (Inches)	Incident Energy (Cal/cm^2)	Required Clothing
MCC MAIN	0.48	B NPC SES	Other	32	17.88	8.71	0.237	0	0.237	59.1	18	6.9	#2
MCC	0.48	B MCC-MAIN	MCC	25	17.88	10.81	0.025	0	0.025	13.7	18	1	#0
H1	0.48	B H1	Panelboard	25	18.22	10.98	0.025	0	0.025	13.3	18	0.9	#0
L1	0.24	B T-L	Panelboard	25	2.217	1.08	15.374	0	15.374	262.6	18	97.6	Not Calculated based on <125kVA, 120/208V
L2	0.24	B T-L	Panelboard	25	2.195	1.07	15.6	0	15.6	263.7	18	98.2	Not Calculated based on <125kVA, 120/208V
L3	0.24	B L2-MAIN	Panelboard	25	4	2.36	0.019	0	0.019	4.2	18	0.1	#0
LIFT PMP1	0.48	B LIFT PMP1	Other	32	17.418	10.03	0.025	0	0.025	11.8	18	0.8	#0
LIFT PMP2	0.48	B LIFT PMP2	Other	32	17.418	10.03	0.025	0	0.025	11.8	18	0.8	#0
LIFT PMP3	0.48	B LIFT PMP3	Other	32	17.418	10.03	0.025	0	0.025	11.8	18	0.8	#0
PKG BIOFLTR	0.48	B PKG BIOFLTR	Other	32	12.76	7.74	0.025	0	0.025	11.7	18	0.8	#0
T-L H	0.48	B T-L	Other	32	18.148	10.38	0.025	0	0.025	12.1	18	0.8	#0
T-L L	0.24	B T-L	Other	32	2.265	1.07	15.629	0	15.629	350.9	18	95.3	Not Calculated based on <125kVA, 120/208V
ATS-1	0.48	B NPC SES	ATS	32	18.341	8.90	0.228	0	0.228	58.3	18	6.8	#2
TX NPC H	12.47		Other	153	0.371	0.38				0	18		No Valid Trip Device Found Upstream or in Bus Dialog.
TX NPC L	0.48		Other	32	22.248	12.30				0	18		No Valid Trip Device Found Upstream or in Bus Dialog.
NPC MTR	0.48		Switchgear	32	21.45	11.93				0	18		No Valid Trip Device Found Upstream or in Bus Dialog.
GEN-1	0.48		Other	32	3.282	2.50				0	18		No Valid Trip Device Found Upstream or in Bus Dialog.

Arc Flash Labels

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

1' - 1"	Flash Hazard Boundary
0.9	cal/cm2 Flash Hazard at 18 Inches
#0	PPE Level
	Non-melting, flammable materials

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: H1

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

1' - 0"	Flash Hazard Boundary
0.8	cal/cm2 Flash Hazard at 18 Inches
#0	PPE Level
	Non-melting, flammable materials

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: LIFT PMP1

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

1' - 0"	Flash Hazard Boundary
0.8	cal/cm2 Flash Hazard at 18 Inches
#0	PPE Level
	Non-melting, flammable materials

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: LIFT PMP2

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

1' - 0"	Flash Hazard Boundary
0.8	cal/cm2 Flash Hazard at 18 Inches
#0	PPE Level
	Non-melting, flammable materials

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: LIFT PMP3

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

1' - 2"	Flash Hazard Boundary
1	cal/cm2 Flash Hazard at 18 Inches
#0	PPE Level
	Non-melting, flammable materials

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: MCC

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

4' - 11"	Flash Hazard Boundary
6.9	cal/cm2 Flash Hazard at 18 Inches
#2	PPE Level
	Cotton underwear plus FR shirt and FR pants

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: MCC MAIN

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

1' - 0"	Flash Hazard Boundary
0.8	cal/cm2 Flash Hazard at 18 Inches
#0	PPE Level
	Non-melting, flammable materials

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: PKG BIOFLTR

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

1' - 0"	Flash Hazard Boundary
0.8	cal/cm2 Flash Hazard at 18 Inches
#0	PPE Level
	Non-melting, flammable materials

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: T-L H

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

29' - 3"	Flash Hazard Boundary
95.3	cal/cm2 Flash Hazard at 18 Inches
	Extreme Danger
	Dangerous work hazard; Energized work prohibited.

0.24	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
0' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 0"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: T-L L

Arc Flash Data based on 02-06-2006 Report

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

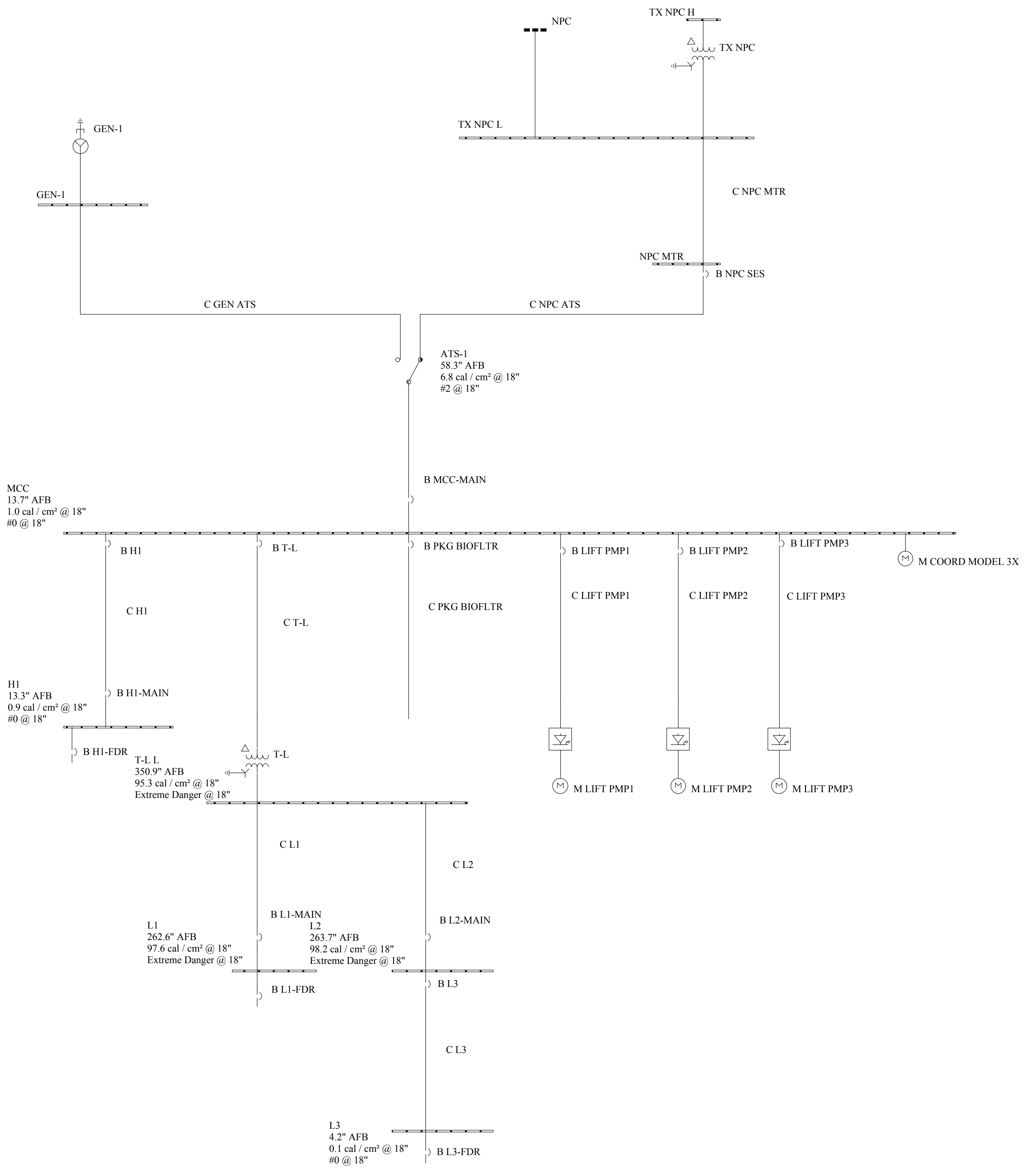
4' - 10"	Flash Hazard Boundary
6.8	cal/cm2 Flash Hazard at 18 Inches
#2	PPE Level
	Cotton underwear plus FR shirt and FR pants

0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 Voltage Gloves

Equipment Name: ATS-1

Arc Flash Data based on 02-06-2006 Report

Single Line Diagram



Clark County Water Reclamation District
Pebble #2 Lift Station - Single Line Diagram AF
PQTSi - February 6, 2006

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