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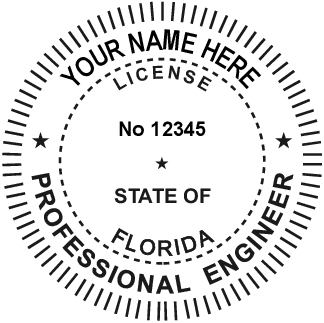
Nowhere, FL 99999

Project Number: BR549

Submitted by:

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Electrical Engineer



Your N. Here, PE

**Power Systems Studies**

for

**Commercial Building - Somewheresville, FL**

Client: Betazoid Development, LLC

Revision 0

June 8, 2024

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**TABLE OF CONTENTS**

[1.0 EXECUTIVE SUMMARY 4](#_Toc67048705)

[1.1 General](#_Toc67048706)

[1.2 Scope of Work](#_Toc67048707)

[1.3 Results and Recommendations](#_Toc67048708)

[2.0 SHORT-CIRCUIT ANALYSIS 7](#_Toc67048710)

[2.1 General](#_Toc67048711)

[2.2 Objectives](#_Toc67048712)

[2.3 Equipment Evaluation](#_Toc67048713)

[2.4 Short-Circuit Results](#_Toc67048714)

[3.0 PROTECTIVE DEVICE COORDINATION STUDY 9](#_Toc67048715)

[3.1 General](#_Toc67048716)

[3.2 Objectives](#_Toc67048717)

[3.3 Codes and Standards](#_Toc67048718)

[3.4 Coordination Data](#_Toc67048719)

[3.5 Coordination Results](#_Toc67048720)

[3.6 Time-Current Characteristic Plots](#_Toc67048721)

[4.0 ARC FLASH INCIDENT ENERGY ANALYSIS 13](#_Toc67048723)

[4.1 General](#_Toc67048724)

[4.2 Objectives](#_Toc67048725)

[4.3 Arc Flash Incident Energy Analysis Results](#_Toc67048726)

[4.4 Arc Flash Report Heading Descriptions](#_Toc67048727)

[4.5 Arc Flash Labels](#_Toc67048728)

[4.6 Arc Flash Recommendations](#_Toc67048729)

APPENDIX A - UTILITY DATA

APPENDIX B - UNBALANCED FAULT REPORT

APPENDIX C - EQUIPMENT EVALUATION REPORTS

APPENDIX D - TCC PLOTS - eXISTING

APPENDIX E - TCC PLOTS - rECOMMENDED

APPENDIX F - sETTINGS rEPORT - eXISTING

APPENDIX G - sETTINGS rEPORT - rECOMMENDED

APPENDIX H - ARC FLASH REPORT - eXISTING CONDITIONS

APPENDIX I - ARC FLASH REPORT - aFTER RECOMMENDED SETTINGS CHANGES

APPENDIX J - ARC FLASH LABELS

Appendix K - ONe-line diagram

# EXECUTIVE SUMMARY

## General

This summary report contains the results of analyses performed on the electrical distribution system for the Commercial Building in Somewheresville, FL. The purpose of this study is to evaluate electrical equipment used in this facility and provide adjustable circuit breaker settings and arc flash labels to the Client. System data and necessary modeling assumptions are provided under Section 2.0 – SHORT CIRCUIT ANALYSIS. A detailed One-line Diagram was developed from data supplied by the Client and on-site survey.

## Scope of Work

### Short-Circuit Analysis

Model the distribution system in SKM PTW® using the SKM Comprehensive Method and perform a short-circuit study to determine the available fault current at all busses throughout the distribution system. The scope of the study includes:

• Analysis beginning at the incoming 480 volts distribution secondary side of the Utility Transformer, continues through the entirety of the system as shown in the One-line drawing.

• Input data used in this study was furnished by the Client as well as on-side system survey performed by COMPANY.

• The available fault currents calculated by the short-circuit study were used in the short circuit analyses. The incoming utility company available fault current data was supplied by the serving utility company, POCOEnergy.

### **Equipment Evaluation**

Evaluate protective devices and busses using the SKM PTW® Equipment Evaluation Tool to determine if any devices or equipment is over-dutied or under-rated.

### **Coordination Study**

Develop time-current coordination plots to derive coordinated settings for protective devices.

### **Arc Flash Analysis**

Perform an arc flash incident energy analysis per NFPA 70E-2024, National Electrical Safety Code and IEEE 1584-2018 on the electrical distribution system and print labels on Avery® label stock.

An incident energy analysis is defined by NFPA 70E to be a component of an arc flash risk assessment used to predict the incident energy of an arc flash event for a specified set of conditions.

### **Recommendations**

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

## Results and Recommendations

### Short-Circuit Study

The system was modeled for available bolted fault currents. 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. Refer to the Appendices for Utility Data, Fault Current Report and the Final One-line diagram.

### Equipment Evaluation

The Equipment Evaluation is based on the power system short-circuit current configuration. The short-circuit ratings of protective devices and other distribution equipment were evaluated using the SKM PTW® Equipment Evaluation Tool.

Panelboards PDP3 and PDP4 and their Square D ED frame feeder breakers failed the evaluation. The ED frame breakers are 18 kAIC rated. There is more than 18kA of adjusted fault current available at these panelboards. There are no published series ratings available for the Square D breakers in PDP3 and PDP4 and the upstream GE circuit breakers. Replacement of all the ED frame breakers in PDP3 and PDP4 with Square D EG framed breakers is recommended. The EG frame breakers are 65kAIC rated at 480V.

The SIFTER Control Panel also failed the evaluation. The label on this control panel indicated that is only 5kA rated. There is more than 5kA of fault current available. Consultation with the control panel manufacturer is necessary to formulate options to remedy this condition.

There were also several other circuit breakers and panelboards in the study with a base AIC rating lower than the available fault current, however, published series ratings were able to be applied to increase the combination rating and pass the evaluation.

Refer to the Appendices for the final Equipment Evaluation Reports.

### Coordination Study

The time-current coordination plots of the protective overcurrent devices are shown in the Appendices. 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 protective devices in the facility. It should be understood that 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.

### Protective Device Settings

Nearly all of the main and feeder breakers on this project are adjustable to at least some degree. Coordination was achieved between all device Long Time and Short time pickup and delay curves between upstream and downstream devices with the existing settings for the most part with a couple of exceptions. Coordination within the Instantaneous region was not able to be achieved in most instances, due to significant overlap in many cases.

There are recommended changes to the settings for the MSB MCB and to EH2 MCB to improve coordination with upstream or downstream devices.

There were also several feeder breakers set to their maximum adjustment. Lowering of these settings to “MIN” does not affect coordination, but does lower the arc flash incident energy at the downstream panelboards. These feeder breakers are LDP L5, LDP L8, LDP L10, LDP L12 AND L13A MCB.

Refer to the Appendices for the Protective Device Settings Reports and the project TCC plots. Reports for existing settings and recommended settings are included.

### Arc Flash Incident Energy Analysis

Details of the arc flash incident energy analysis are shown in Section 4.0. Please note for this study, the arc flash hazard study has been calculated by performing an incident energy analysis per NFPA 70E and IEEE 1584-2018.

Required Arc Flash PPE was determined by calculating the incident energy at the working distance per the equipment type. The incident energy at the working distance is printed on the label as well as the required PPE per NFPA 70E-2024 T130.5(g).

Calculations for two different scenarios were performed per client direction and the scenario resulting in the highest incident energy at each individual bus is used on the arc flash labels. Those scenarios were:

**S0 – Base Project:** Actual available fault current from the Utility Company with emergency loads on Normal Power.

**S1 – Scenario 1:** Actual available fault current from the Utility Company with emergency loads on Generator Power.

Results of the study revealed that the calculated incident energy at the line side of the MSB main circuit breaker was calculated to be in excess of 40 cal/cm2. Calculated incident energy at the line side of disconnect DL13, the line side of LDP MCB, and the line side of L13A MCB and its downstream panels is in excess of 20 cal/cm2. Most other busses are less than approximately 10 cal/cm2 with the majority of busses under 2 cal/cm2.

The incident energy at panels downstream of L13A MCB (panels L13B, L13C and 13D) can be lowered by lowering the setting of L13A MCB.

Incident energy for stand-alone control panels as well as control cabinets that are built-into equipment such as the packaged roof-top units is calculated to the line side of the control panel only. There are too many variables such as voltage, bus gaps and conductor sizes inside the control panel to calculate the incident energy at all point within the control panel.

Refer to the Appendices for the Arc Flash Report and the Arc Flash Labels.

### Exclusions from the study

It should be noted that the transformer and assumed fused disconnect switch feeding the Tenant panel was not accessible. Access to this space was refused by the Tenant. The Tenant equipment was assumed to be located above an inaccessible ceiling space. The Tenant equipment is excluded from the study and no arc flash labels are able to be provided.

# **2.0 SHORT-CIRCUIT ANALYSIS**

## 2.1 General

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. NEC-2023, Articles 110.24(A) and 408.6 requires that service entrance equipment and panelboards are labeled with the following pieces of information:

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

The arc flash labels will include the maximum bolted 3 phase fault current for all busses in this project, not just at the service equipment and panelboards.

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.

Separate "Z" (complex), "X" (reactive), and "R" (resistive) networks are used for the short-circuit analysis. Complex network reduction and the relationship E/Z are used 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. 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, and to evaluate the short-circuit ratings of system components.

The software is capable of generating multiple 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.

For this project, the Unbalanced Fault Report has been generated and included in the Appendices.

## 2.2 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.

### Short-Circuit System Model

The system was modeled for available fault currents. Short-circuit currents were calculated for a three-phase bolted fault and single-line-to-ground fault at each labeled bus shown on the study One-Line diagram.

## 2.3 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 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 Articles 110.9 and 110.10. The device evaluation follows the evaluation procedures outlined in IEEE Std 1584-2018 and applicable ANSI, NEMA, and UL standards.

The results of the short-circuit equipment evaluation are summarized in the Equipment Evaluation Reports in the Appendices. The tables corresponds to bus designations used in the One-Line diagram, "Manufacturer", "Status" (Pass, fail, unknown, or marginal), 'Type" (equipment category), calculated short-circuit duty, the equipment short-circuit rating, and the series rating (if applicable).

Panelboards PDP3 and PDP4 and their Square D ED frame feeder breakers failed the evaluation. The ED frame breakers are 18 kAIC rated. There is more than 18kA of adjusted fault current available at these panelboards. There are no published series ratings available for the Square D breakers in PDP3 and PDP4 and the upstream GE circuit breakers. Replacement of all the ED frame breakers in PDP3 and PDP4 with Square D EG framed breaker is recommended. The EG frame breakers are 65kAIC rated at 480V.

The SIFTER Control Panel also failed the evaluation. The label on this control panel indicated that is only 5kA rated. There is more than 5kA of fault current available. Consultation with the control panel manufacturer is necessary to formulate options to remedy this condition.

There were also several other circuit breakers and panelboards in the study with a base AIC rating lower than the available fault current, however, published series ratings were able to be applied to increase the combination rating and pass the evaluation.

### For low voltage devices:

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

## 2.4 Short-Circuit Results

Results can be found in the Unbalanced Fault Report and are also shown on the One-line diagram.

# PROTECTIVE DEVICE COORDINATION STUDY

## 3.1 General

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

## Objectives

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:

* 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.
* 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 enough impedance between the two devices, such as a transformer.
* 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.

## Codes and Standards

Protective device coordination was performed in accordance with IEEE Std 242™. 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.

Applicable requirements are summarized below.

### Cables

Power cables require overload and short-circuit protection to meet the requirements stated in NEC Article 240, and IEEE Std 242. The NEC further requires that the ampacity of low voltage cable (0-2000 Volts) be determined by NEC Article 310 .15. Cable de-rating based upon ambient temperature and the number of current carrying conductors in a raceway must also be applied. Medium voltage cable (2001-35,000 Volts) ampacity is defined by NEC Articles 240.100(A) and 310 .60.

### Transformers

A transformer is recommended to have protective devices on both primary and secondary side to meet the basic protection requirements for overloads and short-circuit withstand values. However, a transformer is permitted to be protected by only a primary side device if it meets the exceptions listed in NEC Article 240.4(F). In addition, the transformer protective devices must be able to withstand magnetizing inrush currents without tripping.

NEC protection requirements for transformers: Overcurrent devices should be selected, and settings should be recommended to provide overcurrent protection in accordance with NEC Article 450.3. Paragraph (A) specifies that transformers over 600 V comply with Table 450.3(A). Paragraph (B) specifies that transformers less than 600 V comply with Table 450.3(B).

Short-circuit thermal limits for transformers: The primary devices should be set on the basis that the transformers have short-circuit withstand capabilities as defined by IEEE Std C57.109™.

### Motors

The motors should have appropriate protective devices to meet the basic protection requirements for overloads and fault current withstand values. In addition, the motor short-circuit and ground fault protective devices should be set to ride through motor starting current.

## 3.4 Coordination Data

Feeder cable, motor, transformer, generator, circuit breaker and fuse data was furnished by the Client in the form of as-built drawings. Additional data was collected on-site by Company. This data is reflected in the One-line Diagram in the Appendices.

* Duplicate device size and rating is only shown once per TCC plot to reduce clutter.

## 3.5 Coordination Results

The time-current plots each device curve tagged with an arrow and label referencing its location on the plot's individual representative One-Line diagram. 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 in the project. 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.

Nearly all of the main and feeder breakers on this project are adjustable to at least some degree. Coordination was achieved between all device Long Time and Short time pickup and delay curves between upstream and downstream devices with the existing settings for the most part with a couple of exceptions. Coordination within the Instantaneous region was not able to be achieved in most instances, due to significant overlap in many cases.

There are recommended changes to the settings for the MSB MCB and to EH2 MCB to improve coordination with upstream or downstream devices.

There were also several feeder breakers set to their maximum adjustment. Lowering of these settings to “MIN” does not affect coordination, but does lower the arc flash incident energy at the downstream panelboards. These feeder breakers are LDP L5, LDP L8, LDP L10, LDP L12 AND L13A MCB.

Refer to the Appendices for the Protective Device Settings Reports and the project TCC plots. Reports for existing settings and recommended settings are included.

## 3.6 Time-Current Characteristic Plots

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

# ARC FLASH INCIDENT ENERGY ANALYSIS

This section of the report contains the interpretation for the arc flash incident energy analysis. The calculations made in this arc flash incident energy analysis conform to NFPA 70E-2024 and are based on the information provided by the field survey and 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 the latest edition of NFPA 70E should be followed, and in particular appropriate personal protective equipment must be provided and worn.**

COMPANY, Inc. will not be responsible for the misuse or misapplication of the information contained in this analysis. Those providing service for electrical equipment should contact a COMPANY, Inc. representative, or other qualified individual, if any questions arise.

## 4.1 General

NFPA 70E-2024, Article 110.1(G) requires that an employer developed electrical safety program includes a risk assessment procedure that addresses worker exposure to electrical hazards. 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 130.3(B)(1). Selection of personal protective equipment (PPE) should be made based on the incident energy level at the working distance which is presented in this report as part of an arc flash risk assessment to be made by the qualified person. Other components of an arc flash risk assessment including determination of whether or not an arc flash hazard exists for a given work task and the appropriate safe work practices to be employed should be completed by the qualified person performing the work. The risk of arc flash exposure when working on or near electrical equipment depends on a number of factors including the nature of the task being performed and the condition of the equipment. NFPA 70E-2024, Article 130(A) requires that employees use, and employers provide proper PPE for the tasks being performed. NFPA 70E, Table H.3(b) provides guidance for the selection of PPE based on calculated incident energy exposure.

NFPA 70E and IEEE Std 1584 provide equations and methods to 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 hazards 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 required PPE using the arc flash incident energy analysis 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 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 incident energy 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 incident energy 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.

In accordance with NFPA 70E and IEEE Std 1584, the 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/cm2) radiating from a simulated arcing fault at a theorized working distance of 18 inches.

## 4.2 Objectives

The intent of NFPA 70E and IEEE Std 1584 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/cm2 represents the onset of a second-degree burn.

The arc flash incident energy analysis considers each medium and low voltage system location within the scope of the work.

Before the arc flash equations can be applied, a detailed 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.

### Arc Flash Scenarios

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. Study results are based upon the worst-case scenario incident energy.

**S0 – Base Project:** Actual available fault current from the Utility Company with emergency loads on Normal Power.

**S1 – Scenario 1:** Actual available fault current from the Utility Company with emergency loads on Generator Power.

Results of the study revealed that the calculated incident energy at the line side of the MSB main circuit breaker was calculated to be in excess of 40 cal/cm2. Calculated incident energy at the line side of disconnect DL13, the line side of LDP MCB, and the line side of L13A MCB and its downstream panels is in excess of 20 cal/cm2. Most other busses are less than approximately 10 cal/cm2 with the majority of busses under 2 cal/cm2.

The incidence energy at panels downstream of L13A MCB (panels L13B, L13C and 13D) can be lowered by lowering the setting of L13A MCB.

## 4.3 Arc Flash Incident Energy 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 incident energy analysis results shown in Arc Flash Report are based on a protective device clearing time up to a maximum of 2 seconds. This is based on IEEE Std 1584 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.

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, it is essential that the system reliability is not compromised. Settings for protective devices cannot be adjusted if the chance of nuisance trips within critical circuits is introduced. Each location where the incident energy is determined to be unacceptable by the facility Owner, must be individually evaluated to determine the most effective means of reducing the incident energy while maintaining the highest degree of reliability.

## 4.4 Arc Flash Report Heading Descriptions

The Arc Flash Report, shows results of the arc flash incident energy analysis. The following column headings describe the results.

### Bus:

* + - ID: - The names in this column correlate to assigned equipment names.
    - Bus kV: - The values in this column show the nominal voltage of the bus location.
    - Equipment Category: - 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.
    - Electrode Configuration: This column displays the IEEE 1584 Electrode Configuration within a box or enclosure used for the study for each bus. VCBB, VCB or HCB. VCBB was selected for panelboards with main breakers or main molded case switches. VCB was selected for panelboards without a main device. The SKM software then calculated and reported only on the worst case scenario for the VCBB configurations for each bus.
    - Gap (mm) This column displays the spacing between bus bars or conductors at the arc location.

### Fault Current:

* + - Bolted Fault (kA), Bus: - This column shows the bolted fault current available for the equipment 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.
    - Bolted Fault (kA), PD - This column shows the bolted fault current available for the bus protective device location referenced in Column #7. This current value corresponds to the system operating conditions that will result in the worst-case calculated value for incident energy.
    - PD Arc Fault (kA): This column displays the portion of calculated arcing fault currents that is contributed through the protective device. These values demonstrate a reduction in available fault current due to the arc resistance.

### Protective Device:

* + - 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.
    - Trip/Delay time (sec): - This column indicates the time required for a protective circuit breaker device to trip in seconds.

### Arc Flash Boundary (ft):

* + - This column displays the distance within which a person must be clothed in the appropriate PPE (Personal Protection Equipment).

### Incident Energy (cal/cm2):

* + - 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 T130.5(g) provides guidance for the selection of PPE based on calculated incident energy exposure.

### Working Distance (in):

* + - This distance indicates the typical working distance associated with the system location.

### PPE Level:

* + - This column references the level of personnel protective equipment used in previous version of NFPA 70 E. This is not used for the labels on this project.

## 4.5 Arc Flash Labels

Arc flash warning labels are based on the Arc Flash Report results. Labels are provided for each work location and are provided in PDF format for printing on Avery 5524 label stock on a standard office laser printer per Client request. The label shall have an orange header with the wording, "WARNING”.

The label shall include the following information (see example labels below):

* Arc flash boundary
* Incident energy
* Working distance
* Location designation
* Shock Hazard Exposure
* Limited Approach Boundary
* Restricted Approach Boundary
* Minimum PPE Requirements
* Upstream Protective Device
* Maximum available 3 phase bolted fault current at the bus
* Issue date.

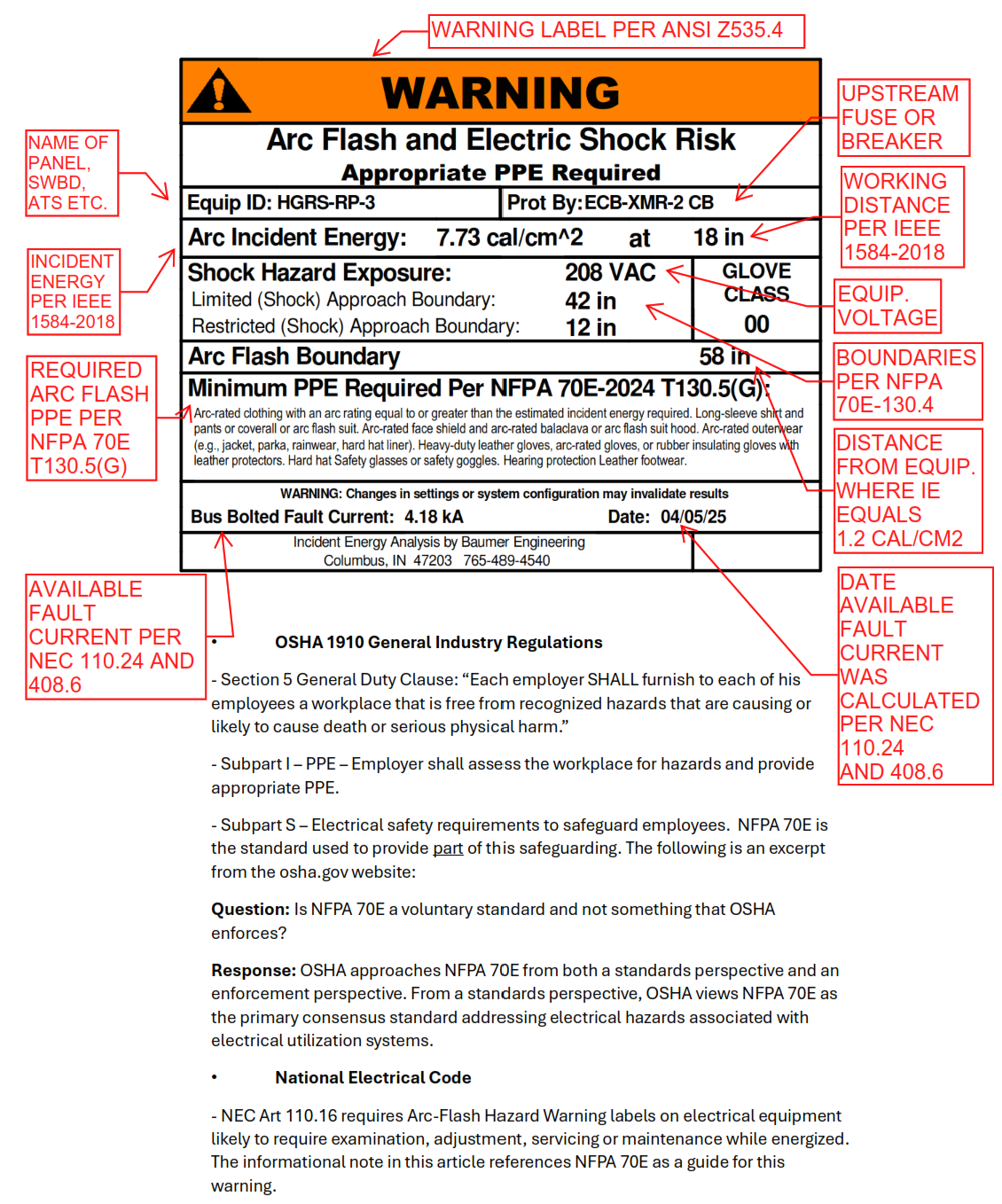
### Electrical Shock Boundaries

Approach boundaries to energized electrical conductors or circuit parts for shock protection (AC systems) are provided on the Arc Flash label. For any given voltage potential, there is a minimum safe electrical distance needed to protect non-insulated body parts from electrical shock. Conditions such as moisture or dust in the air, or altitude affect this minimum distance to some degree. Additionally, depending on the working situation, it may be necessary to add some distance as a safety factor in case of inadvertent movement of a worker's hand or tool.

* **Shock Hazard Exposure:** The normal AC operating voltage of the equipment or conductors where the work is to take place.
* **Limited Approach Boundary:** The closest distance from an exposed, energized (or potentially energized) conductor or part that an **unqualified** worker may approach, unless additional protective measures are used.
* **Restricted Approach Boundary:** The distance from exposed, energized conductors or circuit parts where only qualified workers are allowed, unless additional protective measures are used.

The definitions above used to determine the proper approach distances for Electrical Shock Hazards are based upon NFPA 70E. Refer to NFPA 70E for detailed information on approach boundaries to Energized Electrical Conductors or Circuit Parts for Shock Protection.

It is important to note that the shock protection boundaries and the arc flash boundary are independent of each other.

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**Figure 4.1 - Example Arc Flash Warning Label**

**4.6 Arc Flash Incident Energy Analysis Recommendations**

Results of the study revealed that the calculated incident energy at the line side of the MSB main circuit breaker was calculated to be in excess of 40 cal/cm2. Calculated incident energy at the line side of disconnect DL13, the line side of LDP MCB, and the line side of L13A MCB and its downstream panels is in excess of 20 cal/cm2. Most other busses are less than approximately 10 cal/cm2 with the majority of busses under 2 cal/cm2.

The incident energy at panels downstream of L13A MCB (panels L13B, L13C and 13D) can be lowered by lowering the setting of L13A MCB.

Little can be done to reduce the IE at the line side of the main switchboard MSB without the cooperation of the utility company aside from installing an outdoor main circuit breaker or fused disconnect. That will only move the issue farther upstream. Adding an energy reduction maintenance mode function to the main circuit breaker will not have any effect on the IE at the line side of the main circuit breaker.

To reduce the IE at the line side of the main circuit breaker in switchboard LDP arc flash sensors and current transformers could be added to this switchboard along with interlock wiring to remotely trip the upstream circuit breaker in MSB feeding transformer XL1. This potential solution would need additional research and close coordination with the manufacturer of the distribution equipment to determine if it is possible or feasible. It is likely that breaker MSB LDP would have to be replaced with one capable of shunt trip.

Adding a maintenance mode switch and function to this same upstream breaker may also potentially reduce the IE at LDP by sacrificing downstream coordination with the transformer inrush and main and feeder breakers in LDP when in maintenance mode. This potential would have to be verified and coordinated with the manufacturer as well. It would also like require replacement of the breaker.

Incident energy for stand-alone control panels as well as control cabinets that are built-into equipment such as the packaged roof-top units is calculated to the line side of the control panel only. There are too many variables such as voltage, bus gaps and conductor sizes inside the control panel to calculate the incident energy at all point within the control panel.

APPENDIX A - UTILITY DATA

APPENDIX B – UNBALANCED FAULT REPORT

APPENDIX C - EQUIPMENT EVALUATION REPORTS

APPENDIX D - TCC PLOTS – EXISTING

APPENDIX E - TCC PLOTS - RECOMMENDED

APPENDIX F – SETTINGS REPORTS - EXISTING

APPENDIX G – SETTINGS REPORTS - RECOMMENDED

APPENDIX H - ARC FLASH REPORT – EXISTING CONDITIONS

APPENDIX I - ARC FLASH REPORT – AFTER RECOMMENDED SETTINGS

## APPENDIX J – ARC FLASH LABELS – EXISTING CONDITIONS PLUS EXTRA LABELS IF RECOMMENDED SETTINGS ARE IMPLEMENTED

**LABELS PROVIDED UNDER SEPARATE COVER**

## APPENDIX K – ONE-LINE DIAGRAM