



City of Winnipeg

Roland Flood Pumping Station Arc Flash Study

16 Watt Street



2011/05/18
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May 2011
Revision 00



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1.0 INTRODUCTION

1.1 Background

Roland Flood Pumping Station is located at 16 Watt Street on the east side of the Red River. The pumping station is operated by the City of Winnipeg to provide additional pumping capacity during high river levels. As excess flows can not flow by gravity during high river levels, the flood pumping station is utilized to pump the excess flow, not handled by the wastewater lift station, to the river.

Roland Flood Pumping Station is powered via a bank of three, single phase 150 kVA, City of Winnipeg owned transformers, which are located in a vault. The pumping at the station is comprised of two 150 HP pumps.

1.2 Objective

The City of Winnipeg's flood pumping stations and wastewater lift stations utilize electrical power, which is supplied by Manitoba Hydro and then distributed to various loads in the facilities. City personnel are responsible for operating and maintaining the electrical distribution equipment and must be provided safe working guidelines to perform work on or near the equipment.

The purpose of an arc flash study is to identify and quantify potential arc flash hazards associated with electrical distribution equipment, and establish safe working guidelines for personnel. The safe working guidelines consist of identifying arc flash protection boundaries and the personnel protective equipment (PPE) required for each piece of electrical equipment. This information is identified on a label, which is to be applied to each piece of electrical equipment.

The arc flash hazard analysis is performed in association with a short circuit study and protection device coordination study. Results of the short circuit study are used to determine the available fault current levels at each piece of equipment and results from the coordination study determine the time required for the electrical circuit protective devices to clear the fault condition. The results of these two studies are combined to calculate the incident energy at assigned working positions from the electrical equipment and categorize the arc flash hazard to determine the required PPE to provide adequate protection.



1.3 Scope of Study

The scope of this study is to analyze the electrical distribution as detailed below:

- Investigate the facility to collect data regarding the electrical distribution, equipment nameplate data, and existing protection settings.
- Create or update the electrical system single line diagram to accurately represent the installed electrical system. The drawings will be in AutoCAD format, and transferred to the City for ownership.
- Contact Manitoba Hydro for available utility fault current to the facility.
- Create a software model of the electrical distribution at the station, using the SKM Power Tools software.
- Obtain or create software libraries for protective devices to be utilized in the model.
- Perform a short-circuit study to determine the available fault current at each relevant point within the electrical distribution.
- Perform a coordination study to determine if the existing protection settings of the main distribution breakers are adequate.
- Make recommendations regarding the electrical distribution configuration and protection settings, where required to improve device coordination, or reduce arc flash energies. These recommendations are provided in two phases. Phase 1 recommendations will include minor changes to protective device settings, which can be implemented immediately. Phase 2 recommendations will be comprised of upgrade work to the electrical distribution system.
- Perform an arc flash study to determine the existing potential arc energy levels at the various distribution points, incorporating the proposed Phase 1 recommendations.
- Provide capital costs to perform equipment upgrades to lower fault energies where necessary and practical.
- Provide arc flash labels for electrical equipment.



2.0 METHOD OF STUDY

2.1 Standards

The study is based upon the guidelines specified in the following standards:

- IEEE-1584 – IEEE Guide for Performing Arc-Flash Hazard Calculations
- NFPA-70E – Standard for Electrical Safety In the Workplace
- CSA-Z462 – Workplace Electrical Safety
- IEEE 242 – IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
- IEEE 141 – IEEE Recommended Practice for Electric Power Distribution for Industrial Plants

2.2 System Model

The facility electrical distribution was modelled in software, to allow for software calculation of the study results. This study utilizes software from SKM Systems Analysis Inc. (SKM Power Tools Version 6.5.2.2 - Build 3) to perform the fault current calculations, to produce the required protection coordination curves, and to calculate arc flash energy levels.

Following are the methods utilized in developing the system model.

2.2.1 Utility Contribution

The utility fault levels are provided by Manitoba Hydro at the primary terminals of the supply transformers. Refer to Appendix B for the actual fault reports provided by Manitoba Hydro.

2.2.2 Feeder Conductors

Parameters used in modeling the feeder conductors include: cable type, size, length, conductors per phase, conduit type (magnetic or nonmagnetic), and conductor material. All data was based on available existing single line diagrams, site layout drawings, and visual inspections.

2.2.3 Transformers

Parameters used in modeling the transformers include: transformer type, winding connection, secondary neutral-ground connection, primary and secondary voltage rating, kVA rating, and impedance. Transformer taps and phase shift were unknown and default



values are used. Utility transformer data is based as per information provided by Manitoba Hydro. City owned transformer data is based upon visible nameplates. Where transformer impedance data is not available and cannot be determined from site inspections, values from Table 1, in IEEE Std 242, are used.

2.2.4 Motor Contribution

This short circuit study takes into account the continuous sub-transient fault current contribution of induction motors within the system. The large flood pumping motors are modeled individually in order to accurately determine the motor's fault current contribution. Parameters used in the modeling of induction motors include: operating voltage, horsepower, full-load amps, power factor, efficiency and RPM. Where data was not available, default values (based on similar conditions found at another station) were used.

2.2.5 Assumptions

The following is a list of assumptions that were made about the electrical distribution:

- A Manitoba Hydro owned fused cutout (FDS-XFMR-F1) is feeding three 150 kVA transformers. The size and rating of this fuse could not be obtained and is assumed to be a Cooper T-tin, 140T fuse.
- A nominal transformer impedance of 2.29%, for XFMR-F1, was utilized based on nameplate data. A minimum impedance of 2.06% was utilized based upon the criterion that minimum impedances for City of Winnipeg owned transformers are taken to be 10% less than the nominal impedance. Typical X/R transformer ratios were utilized.
- CP-SPL-F1 is assumed to be 350 MCM, with a length of 1.8m.
- The flood pump motor cable size could not be confirmed through site investigations as it is installed in rigid conduit and the exposed cable in the starters did not have markings. The cable size utilized is based on an original electrical data sheet provided by the City.
- The flood pump reduced voltage starters (autotransformer type) are assumed to limit the starting inrush to less than 4.5x FLA.
- The power fail relay, RLY-F1, is assumed to contain 15A midget supplemental fuses and fed via 12 AWG wire.
- Information on the CEFCO (30A) fuses (FDS-PU-F10 and FDS-FN-F1) found on site could not be obtained. A similar Gould Shawmut NRS fuse was used in the model.
- Cable lengths were measured on site, however they can only be considered as approximations with a tolerance of ± 1.0 m.
- The 25 kVA, 120/240V utility pole-top transformer is assumed to have an impedance of 1.5% based on the Winnipeg Electrical By-Law No. 74/2009.



- The cable from the 120/240V utility pole-top transformer is assumed to be 2 AWG, aluminum to the pole mounted masthead and 78.7m long. The cable from the pole-mounted masthead to PNL-F1, is assumed to be 1/0 AWG copper, and 12m long.
- A ground fault detection system is not present.

2.3 Configuration Scenarios

Worst case incident energy levels do not necessarily occur when fault current levels are the highest. Circuit protection normally consists of a combination of time overcurrent and instantaneous overcurrent where lower level fault currents can cause longer clearing times that may result in higher incident energy levels. The additional clearing time may offset the lower arcing current to produce higher incident energy and consequently a more hazardous condition.

Therefore, different possible electrical distribution configuration scenarios must be analyzed to determine which scenario produces the worst-case arc flash safety hazard and each piece of electrical equipment must be categorized based on the worst-case result.

The following are the electrical distribution configurations at the flood pumping stations that are analyzed as part of this study.

2.3.1 Scenario A – Baseline Fault Level (Normal Operation)

Scenario A is based upon a system configuration which would generate typical short circuit fault levels. The system configuration includes:

- Normal utility fault level.
- Nominal utility transformer impedance.
- The pump motors are not operating.

2.3.2 Scenario B – Maximum Fault Level

Scenario B is based upon a system configuration which would generate maximum short circuit fault levels. The system configuration includes:

- Maximum (horizon) utility fault level.
- Minimum utility transformer impedance (nominal – 10%)
- The pump motors are running.



3.0 SHORT CIRCUIT STUDY

3.1 Short Circuit Calculation Method

A short circuit study is performed to determine the available fault levels for the major 600V, 240V and 208V busses within the pumping station's electrical distribution. This study is necessary in order to find the symmetrical RMS bolted fault current at each point of concern in the electrical distribution, which is then used to calculate the arc fault current. Arc currents are lower than bolted fault currents due to the arc impedance, however they can persist longer than the full bolted fault depending on the protective device time current curves. The results of this study are also used to ensure that interrupting current ratings of the equipment exceeds the calculated maximum available fault current and in determining selectivity and protection settings, as part of the coordination study.

The calculations were performed using the *A_FAULT* module from SKM Systems Analysis Inc. This module follows the specifications of the ANSI standard C37.010, C37.5 and C37.13 and IEEE Standard 141 (Red Book).

The short circuit calculations are based upon Scenario B, described in Section 2.3.2. Note that the Winnipeg Electrical Bylaw requires that an infinite bus be assumed at the primary of the utility transformer, when calculating short circuit currents for equipment ratings of new construction. The requirement of this clause in the bylaw, is based upon the authority's desire to avoid the case where changes in the utility's distribution system will cause equipment within a customer's facility to be incorrectly rated. However, in this case, the installation is existing. By assuming a minimum transformer impedance and horizon utility fault levels, the short circuit values produced in this study are deemed to be safe and conservative, for evaluation of equipment ratings. However, for any new construction within the facility, the requirement to assume an infinite utility bus would apply, which would increase the short circuit currents and potentially the required equipment ratings.



3.2 Utility Contribution

The following table is a summary of the available fault levels at the pumping station provided by Manitoba Hydro. Refer to Appendix B for the official fault study report.

	Normal (Amps)	Horizon (Amps)
3 Phase (L-L-L)	3359	3545
Single Phase – GND (S-L-G)	2241	2284
System Impedances (ohms)	Pos. 2.7704 + j 3.0654 pu Zero. 5.7488 + j 8.6286 pu	Pos. 2.7545 + j 2.9247 pu Zero. 5.7201 + j 8.5147 pu

Table 3-1: Roland Station - Manitoba Hydro Fault Level Summary

3.3 Short Circuit Fault Levels

The following table summarizes the calculated short circuit fault levels at the electrical equipment in the flood pumping station. The fault levels presented are based on the calculations for the maximum fault level scenario.

ID	Description	3P		SLG	
		I _{sc} (Amps)	X/R	I _{sc} (Amps)	X/R
XFMR-F1	Flood Pump Station – Incoming Transformer	13,393	2.9	0	1.0
SPL-F1	Flood Pump Station – Main Splitter	13,256	2.9	0	1.0
CB-P-F1	Flood Pump Station – P-F1 Circuit Breaker	13,148	2.9	0	1.0
CB-P-F2	Flood Pump Station – P-F2 Circuit Breaker	13,148	2.9	0	1.0
RLY-F1	Flood Pump Station - Power Fail Rely	11,905	1.8	0	1.0
FDS-PU-F10	Flood Pump Station – Dewatering Pump Fused Disconnect Switch	12,380	2.1	0	1.0
FDS-FN-F1	Flood Pump Station – Fan Fused Disconnect Switch	12,381	2.1	0	1.0
FDS-SPARE	Flood Pump Station – Fused Disconnect Switch	12,380	2.1	0	1.0
MS-P-F1	Flood Pump Station – P-F1 Motor Starter	12,936	2.9	0	1.0
MS-P-F2	Flood Pump Station – P-F2 Motor Starter	12,936	2.9	0	1.0
MS-FN-F1	Flood Pump Station – Dewatering Pump Starter	5,715	0.5	0	1.0



ID	Description	3P		SLG	
		I _{sc} (Amps)	X/R	I _{sc} (Amps)	X/R
PNL-F20	Flood Pump Station - 120/240V Panelboard	3,863	0.8	3,436	0.8

Table 3-2: Roland Station - Short Circuit Currents

Notes:

1. *Utility fault currents were not obtained for the 120/240 VAC service (PNL-F1). For the 120/240V service, the fault current calculated is based upon an assumed 1.5% transformer impedance and an infinite utility bus.*

The short circuit currents were compared against the interrupting ratings of the protective equipment. In all cases, the existing equipment ratings exceeded the short circuit current, except as noted below:

- The fuses in FDS-PU-F10, and FDS-FN-F1, are assumed to be Class H, which have a 10KA interrupting rating. This fuse rating is below the available fault current. It is recommended to investigate these fuses and replace the fuse/fused disconnect as required to achieve sufficient interrupting capacity. For any new equipment, a minimum 22KA interrupting rating is recommended.
- The power fail relay, RLY-F1, is assumed to be protected by 15A midget fuses, which have a 10KA interrupting rating. The fault current is above this rating therefore, it is recommended to install appropriately rated branch circuit protection upstream of the power fail relay.



4.0 COORDINATION STUDY

4.1 Objectives

A review of the protection settings is performed to ensure that protection devices are set properly for the supplied loads, and to minimize arc flash and potential equipment damage in the event that a fault occurs.

There are three main objectives, in order of priority, to the selective coordination of overcurrent protection devices:

- The first objective is life safety. If reasonable, protective devices should be set at the lowest possible setting that allows normal operation of the connected loads. In the event that a fault does occur, lower protection settings will often provide faster pickup of the fault condition, and consequently reduce the resultant arc fault energy levels.
- The second objective is equipment protection. Protection requirements are met if overcurrent devices are set above load operating levels and below equipment damage curves. This allows normal operation without causing nuisance trips while still protecting equipment against damage should a fault occur.
- The third objective is selective coordination. Where possible, overcurrent protection devices are coordinated such that in the event of a fault, the smallest possible distribution area is removed from service.

Often it is impossible to meet all three objectives because they have conflicting requirements. In order to reduce arc flash energies, protection settings must be set to pickup as fast as possible and clear the fault quickly. However, coordinating upstream breakers with downstream breakers is often achieved by introducing time delays in the upstream breakers to allow the downstream breakers time to trip first. This results in longer fault clearing times for the upstream equipment and increased arc fault energies.

This study attempts to meet all three objectives, but where it is not possible, life safety and equipment protection requirements take precedence.

4.2 Utility Services

Currently, Roland Flood Pumping Station has two utility services. A 600V service powers the pumps and a 120/240V service powers miscellaneous loads including lighting and pump controls. The 600V service is dedicated to the pumping station, but the 120/240V service is shared with nearby residential customers. It is possible, although not a frequent situation, that an event on a nearby residential property could cause the 120/240V utility transformer fuse to blow, resulting in a power failure for the pumping station 120/240V loads.

It is also noted that the 600V distribution system is a delta connected system and no ground fault detection device is installed. As per CEC 10-106(2), ungrounded (delta) systems



require a suitable ground detection device to indicate the presences of a ground fault. A ground fault detection device would allow maintenance electricians to identify that a ground fault has occurred, and make repairs before a second ground fault takes place. Should a second ground fault occur on a different phase from the first, there is the possibility of disruption in station operation due to an overcurrent device opening. In some installations, a simple three-light ground fault detection system is utilized. However, give that this facility is unmanned, it is recommended to provide ground fault alarming through the SCADA system. Alternatively, the 4160V-600V transformer could be replaced with a delta-wye transformer, which does not require ground fault detection.

4.2.1 Proposed Phase 1

No work is proposed as part of Phase 1.

4.2.2 Proposed Phase 2

It is recommended that the City modify the electrical distribution and install a 120/240V transformer to feed PNL-F20 from the 600V service.

4.3 Flood Pump Coordination

4.3.1 Existing

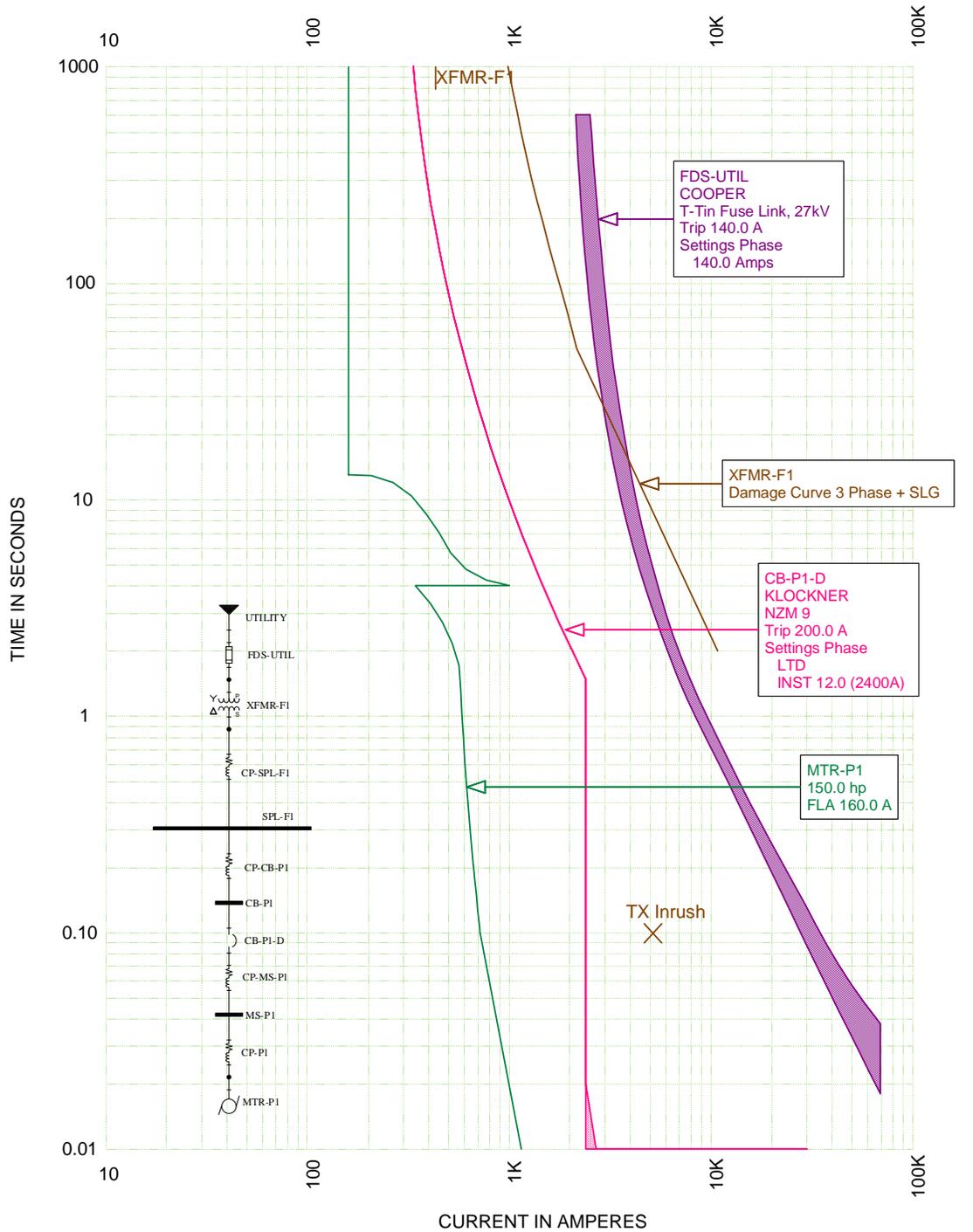
The selective coordination of the protective devices associated with the flood pumps was accessed. The existing time current curves are shown in Figure 4-1.

4.3.2 Proposed Phase 1

There are no proposed Phase 1 changes to the protective device configuration of the flood pump.

4.3.3 Proposed Phase 2

There are no proposed Phase 2 changes to the protective device configuration of the flood pump.



TCC Name: Flood Pump
Scenario: Existing

Current Scale: x 1

Reference Voltage: 600

Figure 4-1 - Roland Flood Pump - Existing TCC Curve



5.0 ARC FLASH STUDY

5.1 Arc Flash Method

The arc flash calculations are calculated utilizing

- The arc flash analysis methodology is based on IEEE Standard 1584-2002.
- The arc flash results are based on worst case incident energies calculated from the scenarios established in Section 2.3.

The results of the arc flash study are based on the available fault currents calculated at each piece of equipment and the coordination study results which determine the time required for the electrical circuit protective devices to clear the fault condition. The worst case arc flash energies calculated from the two scenarios identified in section 2.3 were used to classify the arc flash hazard for each piece of equipment.

Safe working guidelines and recommended personnel protective equipment (PPE) required for each arc flash category are given.

5.1.1 Assumptions

The following assumptions were used in the arc flash analysis:

- Electrical equipment, 240V and less, that is fed from a single transformer less than 125 kVA is assumed to have a classification of Category 0, as per IEEE Std 1584.
- The maximum arcing time duration is 2 seconds for incident energy calculations as per IEEE Std 1584. This is a reasonable time to expect a person exposed to an arc flash to move away from the location.
- The cleared fault threshold is 80% of the total arcing fault current. In other words, for busses with multiple sources of fault current, the fault is considered cleared when protection devices have clear 80% of the total arcing fault.
- Low voltage arc fault tolerances are defined as -15% and 0% as per IEEE Std 1584. Incident energies are calculated at the low and high tolerances to account for arcing fault current variability which can produce varying protection trip times. The largest incident energy is reported.

5.2 Arc Flash Results

The following arc flash results are based on a system model configured with the proposed Phase 1 settings. The arc flash levels were considered while developing the proposed settings, and arc flash energies are set as low as possible without compromising facility



operation. As described in Section 2.3, the presented incident energy is the higher of two scenarios analyzed. The arc flash results can be summarized as follows:

- All 600V distribution equipment at or prior to the first protective device is a Dangerous arc flash hazard. No protective equipment will protect the worker in the event of as fault. Energized electrical work should be prohibited.

ID	Description	Incident Energy (cal/cm ²)	Hazard/ Risk Category
XFMR-F1	Flood Pump Station – Incoming Transformer	54.9	Dangerous!
SPL-F1	Flood Pump Station – Main Splitter	55.5	Dangerous!
CB-P-F1	Flood Pump Station – P-F1 Circuit Breaker	55.9	Dangerous!
CB-P-F2	Flood Pump Station – P-F2 Circuit Breaker	55.9	Dangerous!
RLY-F1	Flood Pump Station - Power Fail Relay	58.2	Dangerous!
FDS-PU-F10	Flood Pump Station – Dewatering Pump Fused Disconnect Switch	59.1	Dangerous!
FDS-FN-F1	Flood Pump Station – Fan Fused Disconnect Switch	59.1	Dangerous!
FDS-SPARE	Flood Pump Station – Fused Disconnect Switch	59.1	Dangerous!
MS-P-F1	Flood Pump Station – P-F1 Motor Starter	0.4	Category 0
MS-P-F2	Flood Pump Station – P-F2 Motor Starter	0.4	Category 0
MS-FN-F1	Flood Pump Station – Dewatering Pump Starter	0.2	Category 0
PNL-F20	Flood Pump Station - 120/240V Panelboard	Note 1	Category 0

Table 5-1: Roland Station - Arc Flash Hazard Classification

Note:

1. *The transformer hazard/risk category is based on the higher of the primary or secondary energy levels. In this case the utility pole-top transformer voltage is 240 volts or less, and the transformer size is less than 125 kVA, thus the transformer secondary hazard/risk category is Category 0, along with any downstream equipment.*

5.2.1 Proposed Phase 2 Mitigation

It is recommended that a main incoming breaker that offers adjustable LSI trip settings be introduced into the existing distribution in order to reduce the dangerous arc flash hazard seen by most of the equipment within the flood pump station. A new distribution panel,



which also addresses the interrupting ratings of the fused disconnects, as discussed in Section 3.3, is recommended. Appropriate settings to provide protection, coordination and lowest possible arc flash energies would be determined as part of detailed design.

5.3 Recommended Personal Protective Equipment (PPE)

The following is a summary of the personal protective equipment recommended by CSA Z462-08 for each hazard category. Refer to the CSA Z462-08 standard for more detailed information.

Category 0 PPE requirements:

- Natural fibre long sleeve shirt and pants (no synthetic shirts, pants, or undergarments)
- Safety glasses or safety goggles
- Hearing protection (ear canal inserts)
- Leather gloves as needed (optional)

Category 1 PPE requirements:

- Arc-rated long sleeve shirt and pants or arc-rated coverall (minimum arc rating of 4 cal/cm²)
- Hard hat with arc-rated face shield or arc flash suit hood (minimum arc rating of 4 cal/cm²)
- Arc-rated jacket, parka, or rainwear as needed
- Safety glasses or safety goggles
- Hearing protection (ear canal inserts)
- Leather gloves
- CSA approved safety boots with dielectric rating and leather uppers as needed (for work with exposed live conductors)

Category 2 PPE requirements:

- Arc-rated long sleeve shirt and pants or arc-rated coverall (minimum arc rating of 8 cal/cm²)
- Hard hat with arc-rated face shield or arc flash suit hood (minimum arc rating of 8 cal/cm²)
- Arc-rated jacket, parka, or rainwear as needed
- Safety glasses or safety goggles
- Hearing protection (ear canal inserts)



- Leather gloves
- CSA approved safety boots with dielectric rating and leather uppers

Category 3 PPE requirements:

- Total FR clothing system and hood (minimum arc rating of 25 cal/cm²)
- Hard hat
- Hearing protection (ear canal inserts)
- Arc flash rated gloves
- CSA approved safety boots with dielectric rating and leather uppers

Rubber gloves with leather protectors are required for work near exposed energized conductors. Ensure that the rubber gloves are voltage rated to a minimum of 1000V. Non-rated rubber gloves should not be used around electrical equipment as the perceived safety may not be provided.



6.0 RECOMMENDATIONS

6.1 Phase 1 Required Work

The following work is required to achieve the goals set forth in this study:

- Apply the arc flash labels provided as part of this study.
- Attach new identification lamacoids to equipment, as noted on the single line drawing.

6.1.1 Cost Estimate

A cost estimate for the Phase 1 work is shown below:

Description	Cost
New identification lamacoids	\$ 100
Total	\$ 100

Notes:

1. *It is assumed that the work will be performed by City forces, and thus no cost allowance for labour or field materials has been included.*

6.2 Phase 2 Recommendations

It is recommended that the City initiate a project to perform the following additional work. Note that the provided arc flash stickers do not include these Phase 2 recommendations, and updated arc flash stickers will be required as part of the proposed Phase 2 work.

1. Install a new 600V distribution panel with a main incoming breaker that offers adjustable LSI trip settings. Appropriate settings to provide protection, coordination and lowest possible arc flash energies will have to be determined.
2. Replace the separate 120/240V service with a 600V-120/240V dry type transformer within the station.
3. Replace the existing vault containing three transformers with a single delta-wye padmount transformer.
4. If the ungrounded 600V system is retained, install a ground fault detection system with a connected SCADA alarm.
5. Replace overcurrent protection for the power fail relay.



6.2.1 Cost Estimate

A cost estimate for the proposed Phase 2 work is shown below:

Description	Cost
Replace pumping station electrical distribution	\$ 65,000
Replace the separate 120/240V service with a transformer	\$ 8,000
Replace the transformer vault with a padmount transformer	Note 2
Install ground fault detection system	Note 3
Indirect Costs	\$ 6,000
Total	\$ 79,000

- 1. The above cost estimate is a Class C estimate and includes contractor costs only.*
- 2. The costs for a padmount transformer are highly dependent upon the configuration and whether the transformer is utility owned. Thus, no costs are provided. It is recommended that the City initiate a preliminary design project to prepare a preliminary design and cost estimate.*
- 3. A ground fault detection system is only required if the 4160V-600V transformers are retained. Approximate cost would be \$5000.*

6.3 Additional Consideration

The flood pump motor starters (MS-P-F1, MS-P-F2) were installed in the 1950's and are obsolete. Therefore, due to age, it is recommended to consider replacement with a modern reduced voltage starter. However, this upgrade is not related to arc flash mitigation or selective coordination and thus is only offered as potential related work.

APPENDIX A : LIST OF ASSOCIATED DRAWINGS

Drawing Number	Title
1-0179F-E0001	Single Line Diagram

APPENDIX B : MANITOBA HYDRO FAULT LEVEL REPORTS

MANITOBA HYDRO
INTEROFFICE MEMORANDUM

FROM John Ermitanio
Technical Support - Student
Distribution Engineering - Winnipeg
Customer Service & Distribution
1120 Waverley Street, Winnipeg, MB

TO Brian Adamyk
South East Energy Services Advisor
Major Account Department
Customer Care & Marketing
360 Portage Ave (6), Winnipeg MB

DATE 2009-08-18

SUBJECT UTILITY INFORMATION REQUIRED FOR ROLAND PUMPING STATION

Customer Information

Name: City of Winnipeg - Water and Waste
Address: **16 Watt Street**

Source Information

Station: **Martin & Rover**
Feeder: **1756N3**

Fault Levels at Point of Delivery^{1, 2}

Switching Configuration	Voltage (kV)	LLL (Amps)	LG (Amps)	R1 (pu)	X1 (pu)	R0 (pu)	X0 (pu)
Normal System Operation ³	4.16	3359	2241	2.7704	3.0654	5.7488	8.6286
Rover Bank 31, 32, & 33 Paralleled - Fully Networked	4.16	3454	2284	2.7545	2.9247	5.7201	8.5147

Impedances are per unit on a 100MVA base

Notes

1. These values are reflective of the normal and expected maximum available fault levels at the customer location, depending on the configuration of the supply, and can be used for arc flash hazard calculation.
2. These values are valid for the system configuration at the time of this study. These fault levels and impedances can change in the future as a result of changes to the Manitoba Hydro system, including feeder reconfiguration or reconductoring, increasing the size of substation transformers and from new or reconducted subtransmission lines. While these changes are infrequent in nature, they are not uncommon and Manitoba Hydro does not communicate changes in fault level or impedance information to customers unless a new request is initiated.
3. The Normal switching configuration is intended for overcurrent protection coordination studies, power quality studies, harmonic assessment and mitigation reports, or power factor correction studies only. The normal fault level information is not to be used for equipment rating purposes.

Yours truly,


John Ermitanio



JE/je/356N17_16 Watt St_Arc Fault Memo_2009 08 18.doc

APPENDIX C : SKM INPUT DATA

ALL PU VALUES ARE EXPRESSED ON A 100 MVA BASE.

FEEDER INPUT DATA							
CABLE NAME	FEEDER FROM NAME	FEEDER TO NAME	QTY /PH	VOLTS L-L	LENGTH	FEEDER SIZE	FEEDER TYPE
CP-CB-P-F1	SPL-F1	CB-P-F1	1	600	0.914 METER	3/0	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	0.2641 + J	0.1703	Ohms/1000 m		0.0671 + J	0.0433 PU
	Z0 Impedance:	0.8323 + J	0.4193	Ohms/1000 m		0.2114 + J	0.1065 PU
CP-CB-P-F2	SPL-F1	CB-P-F2	1	600	0.914 METER	3/0	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	0.2641 + J	0.1703	Ohms/1000 m		0.0671 + J	0.0433 PU
	Z0 Impedance:	0.8323 + J	0.4193	Ohms/1000 m		0.2114 + J	0.1065 PU
CP-FDS-FN-F1	SPL-F1	FDS-FN-F1	1	600	0.914 METER	10	Copper
	Duct Material:	Magnetic		Insulation Type:		PVC	Insulation Class: TW
	+/- Impedance:	3.87 + J	0.2802	Ohms/1000 m		0.9833 + J	0.0712 PU
	Z0 Impedance:	12.20 + J	0.6900	Ohms/1000 m		3.10 + J	0.1753 PU
CP-FDS-PU-F10	SPL-F1	FDS-PU-F10	1	600	0.914 METER	10	Copper
	Duct Material:	Magnetic		Insulation Type:		PVC	Insulation Class: TW
	+/- Impedance:	3.87 + J	0.2802	Ohms/1000 m		0.9833 + J	0.0712 PU
	Z0 Impedance:	12.20 + J	0.6900	Ohms/1000 m		3.10 + J	0.1753 PU
CP-FN-F1	MS-FN-F1	BUS-0046	1	600	2.0 METER	10	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	3.87 + J	0.2802	Ohms/1000 m		2.15 + J	0.1557 PU
	Z0 Impedance:	12.20 + J	0.6900	Ohms/1000 m		6.78 + J	0.3833 PU
CP-MS-FN-F1	FDS-FN-F1	MS-FN-F1	1	600	10.3 METER	10	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	3.87 + J	0.2802	Ohms/1000 m		11.14 + J	0.8066 PU
	Z0 Impedance:	12.20 + J	0.6900	Ohms/1000 m		35.12 + J	1.99 PU
CP-MS-P-F1	CB-P-F1	MS-P-F1	1	600	1.8 METER	3/0	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	0.2641 + J	0.1703	Ohms/1000 m		0.1342 + J	0.0865 PU
	Z0 Impedance:	0.8323 + J	0.4193	Ohms/1000 m		0.4228 + J	0.2130 PU
CP-MS-P-F2	CB-P-F2	MS-P-F2	1	600	1.8 METER	3/0	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	0.2641 + J	0.1703	Ohms/1000 m		0.1342 + J	0.0865 PU
	Z0 Impedance:	0.8323 + J	0.4193	Ohms/1000 m		0.4228 + J	0.2130 PU
CP-MS-PU-F10	FDS-PU-F10	MS-PU-F10	1	600	0.914 METER	10	Copper
	Duct Material:	Magnetic		Insulation Type:		PVC	Insulation Class: TW
	+/- Impedance:	3.87 + J	0.2802	Ohms/1000 m		0.9833 + J	0.0712 PU
	Z0 Impedance:	12.20 + J	0.6900	Ohms/1000 m		3.10 + J	0.1753 PU

FEEDER INPUT DATA							
CABLE NAME	FEEDER FROM NAME	FEEDER TO NAME	QTY /PH	VOLTS L-L	LENGTH	FEEDER SIZE	FEEDER TYPE
CP-P-F1	MS-P-F1	BUS-0011	1	600	4.2 METER	3/0	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	0.2641 + J	0.1703	Ohms/1000 m		0.3131 + J	0.2018 PU
	Z0 Impedance:	0.8323 + J	0.4193	Ohms/1000 m		0.9866 + J	0.4970 PU
CP-P-F2	MS-P-F2	BUS-0012	1	600	4.2 METER	3/0	Copper
	Duct Material:	Magnetic		Insulation Type:			Insulation Class: THHN
	+/- Impedance:	0.2641 + J	0.1703	Ohms/1000 m		0.3131 + J	0.2018 PU
	Z0 Impedance:	0.8323 + J	0.4193	Ohms/1000 m		0.9866 + J	0.4970 PU
CP-PNL-F20-1	BUS-0033	MASTHEAD	1	240	15.0 METER	2	Aluminum
	Duct Material:	Non-Magnetic		Insulation Type:			Insulation Class: THWN
	+/- Impedance:	1.10 + J	0.1214	Ohms/1000 m		28.62 + J	3.16 PU
	Z0 Impedance:	1.75 + J	0.3089	Ohms/1000 m		45.50 + J	8.04 PU
CP-PNL-F20-2	MASTHEAD	PNL-F20	1	240	12.0 METER	1/0	Copper
	Duct Material:	Non-Magnetic		Insulation Type:			Insulation Class: THWN
	+/- Impedance:	0.4167 + J	0.1417	Ohms/1000 m		8.68 + J	2.95 PU
	Z0 Impedance:	0.6624 + J	0.3606	Ohms/1000 m		13.80 + J	7.51 PU
CP-PU-F10	MS-PU-F10	BUS-0035	1	600	2.0 METER	10	Copper
	Duct Material:	Magnetic		Insulation Type:		PVC	Insulation Class: TW
	+/- Impedance:	3.87 + J	0.2802	Ohms/1000 m		2.15 + J	0.1557 PU
	Z0 Impedance:	12.20 + J	0.6900	Ohms/1000 m		6.78 + J	0.3833 PU
CP-RLY-F1	SPL-F1	RLY-F1	1	600	0.914 METER	12	Copper
	Duct Material:	Magnetic		Insulation Type:		PVC	Insulation Class: TW
	+/- Impedance:	6.14 + J	0.2986	Ohms/1000 m		1.56 + J	0.0758 PU

Z0 Impedance: 19.34 + J 0.7352 Ohms/1000 m 4.91 + J 0.1867 PU

CP-SPARE SPL-F1 FDS-SPARE 1 600 0.914 METER 10 Copper
 Duct Material: Magnetic Insulation Type: PVC Insulation Class: TW
 +/- Impedance: 3.87 + J 0.2802 Ohms/1000 m 0.9833 + J 0.0712 PU
 Z0 Impedance: 12.20 + J 0.6900 Ohms/1000 m 3.10 + J 0.1753 PU

CP-SPL-F1 XFMR-F1-S SPL-F1 1 600 1.8 METER 350 Copper
 Duct Material: Magnetic Insulation Type: PVC Insulation Class: TW
 +/- Impedance: 0.1240 + J 0.1611 Ohms/1000 m 0.0620 + J 0.0806 PU
 Z0 Impedance: 0.3907 + J 0.3967 Ohms/1000 m 0.1954 + J 0.1984 PU

TRANSFORMER INPUT DATA

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=====
TRANSFORMER PRIMARY RECORD VOLTS * SECONDARY RECORD VOLTS FULL-LOAD NOMINAL
NAME NO NAME L-L NO NAME L-L KVA KVA
=====
XFMR-F1 XFMR-F1-P Y 4160.00 XFMR-F1-S D 600.00 450.00 450.00
Pos. Seq. Z%: 1.07 + J 4.88 (Zpu 2.37 + j 10.85 ) Shell Type
Zero Seq. Z%: 9999. + J 9999. (Pri Open, Sec Open)
Taps Pri. 0.000 % Sec. 0.000 % Phase Shift (Pri. Leading Sec.): -30.0 Deg.

XFMR-F2 BUS-0032 YG 4160.00 BUS-0033 YG 240.00 43.30 43.30
Pos. Seq. Z%: 0.491 + J 1.42 (Zpu 11.35 + j 32.73 ) Shell Type
Zero Seq. Z%: 0.491 + J 1.42 ( Pri - Sec: 11.35 + j 32.73 )
Taps Pri. 0.000 % Sec. 0.000 % Phase Shift (Pri. Leading Sec.): 0.000 Deg.

```

GENERATION CONTRIBUTION DATA

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=====
BUS CONTRIBUTION VOLTAGE
NAME NAME L-L MVA X*d X/R
=====
BUS-0032 UTILITY-120/24 4160.00 5177.59
Three Phase Contribution: 718577. AMPS 1.74
Single Line to Ground Contribution: 484783. AMPS 0.9360
Pos Sequence Impedance (100 MVA Base) 0.0096 + J 0.0167 PU
Zero Sequence Impedance (100 MVA Base) 0.0435 + J 0.0252 PU

XFMR-F1-P UTILITY 4160.00 24.20
Three Phase Contribution: 3358.97 AMPS 1.11
Single Line to Ground Contribution: 2240.64 AMPS 1.31
Pos Sequence Impedance (100 MVA Base) 2.77 + J 3.07 PU
Zero Sequence Impedance (100 MVA Base) 5.75 + J 8.63 PU

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MOTOR CONTRIBUTION DATA

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=====
BUS CONTRIBUTION VOLTAGE BASE Motor
NAME NAME L-L kVA X*d X/R Number
=====
BUS-0011 MTR-P-F1 600 166.89 0.1692 10.0 1.00
Pos Sequence Impedance (100 MVA Base) 10.14 + j 101.38 PU

BUS-0012 MTR-P-F2 600 166.89 0.1692 10.0 1.00
Pos Sequence Impedance (100 MVA Base) 10.14 + j 101.38 PU

BUS-0046 MTR-FN-F1 600 1.14 0.1692 10.0 1.00
Pos Sequence Impedance (100 MVA Base) 1480.20 + j 14802.0 PU

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APPENDIX D : ANSI FAULT SUMMARY

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	A V A I L A B L E		F A U L T D U T I E S (KA)	
	L-L	3 PHASE	X/R	LINE/GRND	X/R
CB-P-F1	600.	13.148	2.91	0.000	1.00
CB-P-F2	600.	13.148	2.91	0.000	1.00
FDS-FN-F1	600.	12.381	2.06	0.000	1.00
FDS-PU-F10	600.	12.380	2.06	0.000	1.00
FDS-SPARE	600.	12.380	2.06	0.000	1.00
MASTHEAD	240.	4.476	0.90	4.072	0.82
MS-FN-F1	600.	5.715	0.52	0.000	1.00
MS-P-F1	600.	12.936	2.85	0.000	1.00
MS-P-F2	600.	12.936	2.85	0.000	1.00
MS-PU-F10	600.	11.495	1.59	0.000	1.00
PNL-F20	240.	3.863	0.80	3.436	0.75
RLY-F1	600.	11.905	1.75	0.000	1.00
SPL-F1	600.	13.256	2.94	0.000	1.00
XFMR-F1-P	4160.	3.658	1.45	2.337	1.47
XFMR-F1-S	600.	13.393	2.93	0.000	1.00

APPENDIX E : ARC FLASH OPTIONS

Standard	IEEE 1584 - 2002/2004a Edition		
Unit	Metric		
Flash Boundary Calculation Adjustments	Equipment above 1 kV and Trip Time <= 0.1 seconds, use 1.5 cal/cm ² (6.276 J/cm ²) for flash boundary calculation		
Equipment 240 V and Below	Report calculated incident energy values from equations		
Short Circuit Options			
Include Transformer Tap	Yes	Pre-Fault Option	No Load with Tap
Include Transformer Phase Shift	No	Define Grounded as SLG/3P Fault >=	5%
Include Induction Motor Contribution	5.0 cycles	Current Limiting Fuse	Specified in library
Reduce Generator/Synch. Motor Contribution to	Do not represent generator and synchronous motor decay		
Line Side Incident Energy Calculation	Include line side + load side fault contributions		
Recalculate Trip Time Using Reduced Current	No	Mis-Coordination Levels to search	1
Use Arc Flash Equations for Breakers and Fuses	Yes	Mis-Coordination Ratio	80%
Report Options			
Report Option	Bus Report	Arcing Fault Tolerance	
Label and Summary View	Report Main Device	Low Voltage In Box (-15%)	0%
Check Upstream Device for Mis-Coordination	Yes	Low Voltage Open Air (-15%)	0%
Cleared Fault Threshold	80.00%	HV/MV In Box	0% 0%
Max Arcing Duration	2 seconds	HV/MV Open Air	0% 0%
Increase PPE Category by 1 for high marginal IE	No		

APPENDIX F : ARC FLASH RESULTS (PHASE 1 MITIGATION)

Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Bus Arcing Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Equip Type	Gap (mm)	Arc Flash Boundary (mm)	Working Distance (mm)	Incident Energy (cal/cm ²)	Required Protective FR Clothing Category
CB-P-F1	FDS-XFMR-F1	0.600	13.2	8.6	11.4	7.44	1.753	0	PNL	25	4764	457	55.9	Dangerous! (*N3) (*S3)
CB-P-F2	FDS-XFMR-F1	0.600	13.2	8.6	11.4	7.44	1.753	0	PNL	25	4764	457	55.9	Dangerous! (*N3) (*S3)
FDS-FN-F1	FDS-XFMR-F1	0.600	12.4	8.13	10.7	7.04	1.959	0	PNL	25	4926	457	59.1	Dangerous! (*N3) (*S3)
FDS-PU-F10	FDS-XFMR-F1	0.600	12.4	8.13	10.7	7.04	1.959	0	PNL	25	4926	457	59.1	Dangerous! (*N3) (*S3)
FDS-SPARE	FDS-XFMR-F1	0.600	12.4	8.13	10.7	7.04	1.959	0	PNL	25	4926	457	59.1	Dangerous! (*N3) (*S3)
MASTHEAD	MaxTripTime @2.0s	0.240	4.48	2.56	4.48	2.56	2	0	PNL	25	458	457	1.2	Category 0 (*N2) (*N9) (*N15) (*S3)
MS-FN-F1	FDS-FN-F1-D	0.600	5.71	4.69	5.71	4.69	0.01	0	PNL	25	149	457	0.2	Category 0 (*S3)
MS-P-F1	CB-P-F1-D	0.600	12.9	9.96	12.1	9.28	0.01	0	PNL	25	245	457	0.4	Category 0 (*S3)
MS-P-F2	CB-P-F2-D	0.600	12.9	9.96	12.1	9.28	0.01	0	PNL	25	245	457	0.4	Category 0 (*S3)
MS-PU-F10	MaxTripTime @2.0s	0.600	7.72	6.19	7.72	6.19	2	0	PNL	25	4518	457	51.3	Dangerous! (*N2) (*N9) (*S2)
PNL-F20	CB-PNL-F20	0.240	3.86	2.3	3.86	2.3	2	0	PNL	25	458	457	1.2	Category 0 (*N9) (*N15) (*S3)
RLY-F1	FDS-XFMR-F1	0.600	11.9	7.84	10.3	6.79	2	0	PNL	25	4881	457	58.2	Dangerous! (*N3) (*N9) (*S3)
SPL-F1	FDS-XFMR-F1	0.600	13.3	8.66	11.5	7.5	1.725	0	PNL	25	4741	457	55.5	Dangerous! (*N3) (*S3)
XFMR-F1	FDS-XFMR-F1	0.600	13.39	8.74	11.61	7.58	1.687	0	PNL	25	4711	457	54.9	Dangerous! (*N3) (*S3)
XFMR-F1-P	FDS-XFMR-F1	4.160	3.66	3.61	3.45	3.41	0.197	0	SWG	104	542	914	0.7	Category 0 (*S3)
Category 0: Untreated Cotton	0.0 - 1.2 cal/cm ²												#Cat 0 = 6	(*N2) < 80% Cleared Fault Threshold
Category 1: FR Shirt & Pants	1.2 - 4.0 cal/cm ²												#Cat 1 = 0	(*N3) - Arcing Current Low Tolerances Used
Category 2: Cotton Underwear + FR Shirt & Pants	4.0 - 8.0 cal/cm ²												#Cat 2 = 0	(*N9) - Max Arcing Duration Reached

Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Bus Arcing Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)	Equip Type	Gap (mm)	Arc Flash Boundary (mm)	Working Distance (mm)	Incident Energy (cal/cm2)	Required Protective FR Clothing Category
Category 3: Cotton Underwear + FR Shirt & Pant + FR Coverall	8.0 - 25.0 cal/cm ²												#Cat 3 = 0	(*N15) - Report as category 0 if fed by one transformer size < 125 kVA
Category 4: Cotton Underwear + FR Shirt & Pant + Multi Layer Flash Suit	25.0 - 40.0 cal/cm ²												#Cat 4 = 0	
Category Dangerous!: No FR Category Found	40.0 - 999.0 cal/cm ²												#Danger = 9	IEEE 1584 - 2002/2004a Edition Bus Report (80% Cleared Fault Threshold, mis-coordination checked)
													Worst Case	(*S2) - Baseline Fault Level
														(*S3) - Maximum Fault Level