ENSURING ACCURACY AND QUALITY WHEN PERFORMING ARC FLASH STUDIES ON LOW-VOLTAGE POWER DISTRIBUTION EQUIPMENT

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Abstract – This paper highlights major findings, challenges, and approaches in which specific techniques had to be incorporated to perform power system studies and arc flash hazard analysis for multiple gas transportation facilities.

This paper will discuss methods to properly determine an accurate bus configuration for various low-voltage (LV) Motor Control Centers (MCCs) in order to meet the current IEEE 1584-2018 standard [1] for proper calculation of the incident energy at various locations. Some of the special techniques and challenges include determining the isolation status of the main circuit breaker, the isolation of low-voltage AC equipment from DC equipment contained within the LV MCC, and an instance in which there were multiple sources of supply contained within the same LV MCC.

This paper will discuss real world applications and experiences throughout this project that could be incorporated into future arc flash study practices. This paper will also discuss quality control measures that were used during the arc flash study projects including field data collection processes, verification walk-throughs, and the owner's Quality Assurance/Quality Control (QA/QC) process.

Index Terms — Arc Flash Hazard Analysis, Incident Energy, Field Data Collection, Motor Control Center, Automatic Transfer Switch, Multiple Power Sources, QA/QC, Life Cycle Management, Management of Change

I. INTRODUCTION

When performing arc flash studies, there are many aspects to consider:

1. A field verification should take place to ensure that the existing electrical one-line drawings match the equipment identification and the name plate data.
2. For items that are not able to be field verified, engineering judgement needs to be applied when information is missing or not readily available.
3. In some applications, there could be multiple energy sources inside the same equipment and those instances needed to be evaluated.
4. A system developed that documents the arc flash study labels and specifies the proper location where the label needs to be applied.
5. Field implementation of the arc flash study recommendations, including the development or utilization of a field QA/QC checklist to review and verify which results have been completed or which ones are outstanding.

II. OBSERVATIONS AND FINDINGS

When performing a field site visit to gather information for the arc flash incident energy analysis, there are several items that the individual gathering the field data should consider when performing the visual inspection. Some examples of those visual inspection items are: wiring condition, installation issues, equipment identification/tagging errors, equipment condition and documentation, and missing information such as electrical utility data or equipment nameplates. See Fig. 1 for an example of an unreadable nameplate installed on an MCC.

Fig. 1 480VAC MCC Bucket with Unreadable Nameplates

The Owner should provide electrical field personnel to support data gathering. The personnel shall be fully qualified to access electrical equipment in compliance with the applicable electrical safety program.

The documentation supplied such as the latest one-line diagram, existing coordination studies, etc. shall be used as the basis of the arc flash study and any items that do not match the documents should be redlined and brought to the attention of the Owner. The equipment identification should be consistent between the one-line, the equipment tag on the electrical equipment, and the actual equipment nameplate.

When collecting the field data, the individual should highlight any issues or concerns that arise such as discolored or damaged wiring, internal or external corrosion including enclosures, any equipment that is damaged or discolored, evidence of vermin or animals, wiring discrepancies, installation issues, or anything that does not appear to be in normal operating condition. See Fig. 2 for an example of a cable installation issue.

Fig. 2 Cable Spliced in Breaker Enclosure

When performing the field site visit, some of the information may be missing, illegible, or unable to be verified such as electrical utility data or equipment nameplate information. Electrical utility information is not always easily available during onsite field visits. Typically, the electrical utility will need to be contacted to verify and/or supply information such as: transformer size and impedance, size and type of protective devices, cable sizing, etc. Occasionally, the electrical utility information such as protective device settings is not available, and the user would need to provide their settings to the utility company so that they can review protective coordination and accept or suggest new protective settings.

- Electrical protective device settings should be verified from the last testing and the settings in the protective device and any discrepancies shall be brought to the attention of the Owner.
- Verify that the protective device is in the "Ready" state or indicates any self-test fault or relay failure and any relay failure shall be brought to the attention of the Owner.
- Any items of interest that are provided to the Owner should be reviewed and validated.

Electrical equipment such as low-voltage switchgear, low-voltage motor control centers, low-voltage panelboards, etc., need to have their nameplate verified against any drawings that are available or were provided. Sometimes, the nameplate information is not available, and the items need to be highlighted so that further research can be performed by reviewing project manuals, Original Equipment Manufacturer (OEM) manuals, past purchase orders, bill of materials, or other documentation that includes the nameplate information.

III. CHALLENGES AND TECHNIQUES

Missing key information for the arc flash study can cause delays and may require utilizing best engineering judgement. In some cases, the information may be present, but it could be incorrect. For an arc flash study to be as accurate as possible, all pertinent data needs to be collected and documented during the data gathering phase if possible. All data obtained should be verified as to its accuracy. For utility data provided, verify the meter number(s), transformer nameplate data, the provided Available Fault Current (AFC), minimum and maximum AFC ranges or tolerances, MVA base, etc. The provided AFC (or short-circuit current) can be checked for accuracy using the MVA method [5] as shown in below:

$$MVAsc = \frac{MV \text{ x } Isc \text{ x } \sqrt{3}}{\%Z} \text{ x } 100 \tag{1}$$

where:

MVA_{SC}	Short-circuit apparent power
MV	System voltage
I_{SC}	Short-circuit current
%Z	System impedance (expressed in percentage)

The equation above can be used to determine the maximum amount of current, I_{SC}, that will flow during a short-circuit or fault condition. It depends on the system voltage and the total connected impedance of the current flow path from a source with infinite capacity at the point of the fault.

In many instances, there is missing data that cannot be determined but may be estimated. For example, if there are fuses with missing labels or identification stickers, etc., an approach would be to use the known cable size to calculate the expected fuse size and ratings. Any tolerances as defined in the National Electrical Code (NEC) should be considered [2]. The fuse's time-current curves can be used to determine the model that yields the slowest trip time, which would yield the highest incident energy. Another option is to omit the fuse from the study or allow the fuse operating time to max out at two seconds to yield conservative results. Two seconds is considered a reasonable assumption for arc duration as it is based on the likelihood that a person could move away from the location of the arc flash [1]. If a worker is restricted in movement, then more time may be needed to move away. In the event there is an adjustable trip circuit breaker with unknown (or unreadable) settings, the device can be modeled with the settings maxed out to yield conservative results. In this case, however, there may be the possibility of an assumed mis-coordination problem with downstream feeder circuit breakers as well, which would require more investigation.

Equipment is often encountered in which the equipment specifications are required to determine the original nameplate data as the original nameplate or tagging is removed, faded, or such and this can cause delays in the project. Obsolete protective devices can be another issue if the original data sheets or time-current curves are not available. In these cases when the information cannot be obtained, some options are to use the data obtained from cross reference tables on similar equipment or to use the data from similar modern models by the same manufacturer. In some instances, manufacturers can be asked to provide a similar or equivalent equipment model type.

Often, the loads or other feeders cannot be determined during the data gathering phase, especially if the electrical one-line diagrams are not up to date. If time permits and if it is in the budget, the loads can be traced out with an electrical trace meter. In most cases, time does not permit this, and an "open items" list is generated for the Owner to help determine the missing information.

IV. APPROACHES

A. Multiple Energy Sources

At several sites, there are multiple energy sources within the LV MCCs. There were instances where DC panelboards were integrated within an entire section of a 480VAC MCC. Also, the 480VAC MCC contained integral 208/120VAC panelboards fed from transformers located both within and external to the MCC. These configurations were found at three sites, and are labelled below "Site 1, 2, and 3".

"Site 1" had a 480VAC MCC in which the main circuit breaker was not isolated from the adjacent MCC sections, as would be considered by IEEE 1584-2018 standard [1], with one section containing a 125VDC panelboard. In this case, there is 480VAC bus passing through a 125VDC section. There is also an integral 120/208VAC panelboard fed from a transformer within the MCC section.

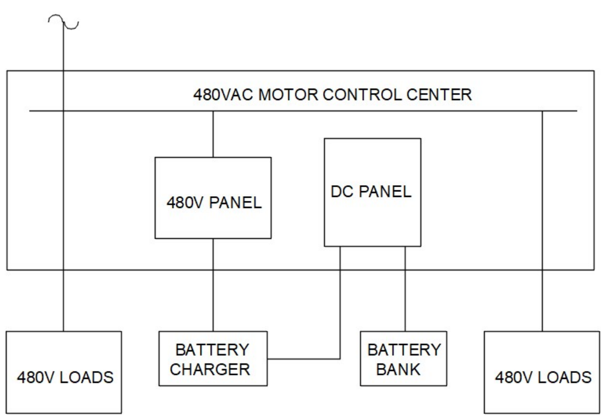

Fig. 3 Site 1: 480VAC MCC with Internal DC Panel

"Site 2" had a 480VAC MCC with one section rated 129VDC that is not completely isolated from the 480VAC bus, as would be considered by the IEEE 1584-2018 standard [1]. Further, the bottom floors of the MCC sections are open to allow the passage of cables through the subfloor.

Fig. 4 Site 2: MCC with 480VAC and 129VDC Sections

Fig. 5 Site 2: 480VAC and 129VDC MCC Sub-Floor

"Site 3" had the generator main circuit breaker located within the MCC, along with the Automatic Transfer Switch (ATS). This is a familiar case of load side vs. line side labels. However, the generator cables are also routed to a load bank located outside via a Disconnect Switch, which also feeds downstream equipment. Therefore, the normal mode of operation is to exercise the generator from the load bank. Hence, the 480VAC MCC would have both utility as well as generator power available when performing a generator test while connected to the load bank. Simultaneously, the utility source is providing power to the site's load. Since the ATS nor the generator circuit breaker are isolated from the MCC bus, the conservative approach is to choose the normal or the generator power source (line-side) that yields the higher incident energy results. An alternative method that may be considered is to utilize the closed transition state for the ATS to take into account the overlap in which both sources are energized. Note that generally an ATS is fed from the utility and generator only momentarily. But any instance where the ATS is fed from a generator with a load bank, both sources would be energized for prolonged periods of time.

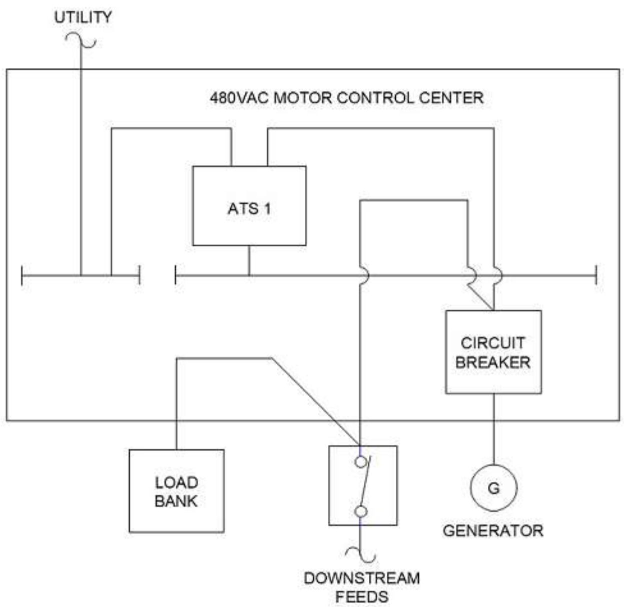

Fig. 6 Site 3: 480VAC MCC with Internal ATS & Generator CB

For these special instances, consider the worst-case perspective in order to fully protect any workers from potential injuries in the event of arc flash incident. For Sites 1 and 2, since the MCC bus and adjacent sections are not truly isolated from the main circuit breaker, the incident energy value from the line-side of the main circuit breaker shall be assumed to be present at each 480VAC MCC section. There are AC and DC calculations to determine the incident energy values. For the labelling on the 125VDC section that contains 480VAC bus, the 480VAC warning label with the higher incident energy values was installed. For the 125VDC panel, the DC label was installed behind the MCC section door, onto the front of the DC panel door. For this label, the higher incident energy value was used.

For Site 3, the worst-case incident energy needs to be determined in normal mode and emergency (generator mode) to include in the calculations or alternatively select a closed-transition state for the ATS.

B. Serialized Placeholder Labels

Placeholder labels are installed as a temporary basis during the initial data gathering phase of each project. These labels have a printed serial number on them that will match the serial numbers on the CAD drawings as well as the final printed arc flash labels. They can be used as an inventory number for reference throughout the life of the equipment. These labels add an extra measure of quality control since these numbers can be used to track the piece of equipment they are placed on throughout the process. Another benefit is that it makes the placement of the final labels quite easy, as you simply match the serial number on the temporary label with the actual arc flash label. The electrical one-line markups created during the data gathering also show the serial number on the associated equipment. Refer to Appendix B, Fig. 10 for an example of how the placeholder labels and arc flash labels are referenced to each other.

Occasionally, some equipment has not been identified and/or properly tagged. In this situation, the owner should be in agreement with any equipment identification tagging or naming that occurs.

Upon completion of the data gathering phase of the project, a table is created that lists the file name of the photographs taken during the data gathering, along with the associated equipment name and/or information, and the serial number of the temporary label that was applied. This table can be used as an inventory tracker for all the associated electrical equipment.

Photo	Label	Equipment
IMG_1965.JPG	101	MSWBD
IMG_1966.JPG	102	MCC-A, SECT. 1
IMG_1967.JPG	103	MCC-A, SECT. 2
IMG_1968.JPG	104	MCC-A, SECT. 3
IMG_1969.JPG	105	MCC-A, SECT. 4
IMG_1970.JPG	106	PNL-B
IMG_1971.JPG	107	LP-1
IMG_1972.JPG	108	DP-1
IMG_1973.JPG	109	LC-1
IMG_1974.JPG	110	LP-2

Fig. 7 Example Photo Identification Table

C. CAD Drawings

CAD drawings are used for the electrical one-line drawings since part of the project scope is to create as-built one-line drawings and they are typically easy to customize. The drawings can be customized to show the required data. The drawback to this is that they need to be inspected carefully as this method can be more prone to errors. As previously mentioned, the CAD files show the equipment serial numbers that will match the arc flash labels, etc.

D. Labelling Methods

It is imperative that the correct arc flash warning labels are installed on the equipment. It needs to be verified that the line-side versus load-side calculations are appropriately matched for the equipment. Another often overlooked, or misunderstood aspect is whether the equipment is truly isolated or not [1]. In this instance, if the main circuit breaker in a MCC is not truly isolated from the downstream bus, an arcing fault could possibly propagate to the downstream bus. Often, the downstream bus calculations are lower due to the typically faster clearing times on the feeder circuit breakers. In this case, the labels would have incorrect information and could potentially become a dangerous situation.

The project scope as agreed to with the Owner is that there will be one arc flash label applied per MCC section unless there are two different voltage sources of equipment or if the calculations result in different incident energy values within the same section. Fig. 8 depicts the label placement for a 480VAC MCC that has a main breaker that is isolated from the downstream bus. The Main Breaker in Section 1 would have a label in which the incident energy is calculated at the line side of the main breaker. The MCC buckets noted as “Misc. Load” would have labels in which the incident energy is calculated at the load side of the main breaker. Note that the clouds at MCC Sections 2 and 4 indicate that there is one label per MCC section. For Section 3, since there is a 480V:208VAC transformer and a 208VAC panelboard, each of these MCC buckets would have a label applied. The 480:208VAC transformer has a primary and secondary label applied since the higher incident energy is typically seen at the secondary of the transformer. In the event of a MCC breaker that is not isolated, each MCC section would have the same incident energy value as that of the main breaker.

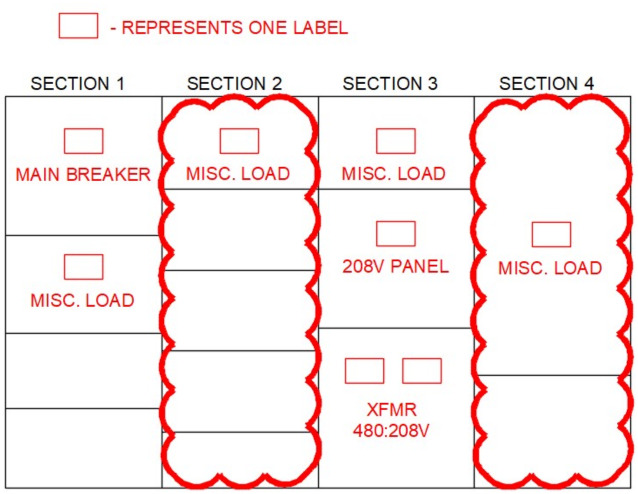

Fig. 8 Label Locations for a MCC with Isolated Main Breaker

Clear overlays on the labels are used to add an extra layer of protection against weathering. They are installed on top of all arc flash labels that are installed on outdoor equipment. They prevent the colors and print form fading and preserve the life of the label. Although it may be more costly, another option would be to have the arc flash labels made out of stainless steel and then attached to the outdoor equipment.

V. TECHNIQUES AND IMPLEMENTATION

When an arc flash study is performed, the consultant who performs the study should include updated one-line drawings along with the study. When the one-line is received, the Owner utilizes it to validate that the site’s equipment was reviewed and modelled correctly.

The owner then physically verifies that the one-line matches the actual installed equipment, such as the equipment tagging, equipment descriptions, equipment ratings, etc. The owner also verifies the time-current curves for proper coordination, and all of the associated breaker and or relay settings, part numbers, ratings, etc. If any discrepancies are found, the owner documents and communicates the findings back to the arc flash study consultant for any required clarifications or corrections.

When the initial draft of the arc flash study is completed, the study is reviewed to determine if any safety issues or concerns are stated in the report. Easily implemented corrections such as protective device settings changes are immediately performed after being reviewed and approved by the owner.

The final step in the review is to research the more complex mitigation recommendations to determine if and how they should be implemented from an operational, budgetary, scheduling, and technical standpoint. The owner maintains the recommendations on a tracking log which is then sent off to the consultant so that a restudy can be completed with the completed recommendations. This is usually done at the final draft stage of the study so that any corrections and changes from the field QA/QC check can be incorporated before preparing the final engineering study and model of record.

Implemented	Approved by	Protective Device Bus ID	Existing Settings I.E.	Recommended Settings I.E.	Reference
3/4/2021	ABC	CB-DS1	(Manuf./Model)	(Manuf./Model)	Table 5.1: Line 1
			1200AF/1000AT	1200AF/1000AT	
			LTD: 2	LTD: 6.5	
			STPU: 2	STPU: 3.5	
		PD Coordination Only	INST: 2	INST: 3	
No		CB-SWGR-3B-Main	(Manuf./Model)	(Manuf./Model)	Table 5.1: Line 1
			800AF/800AT	800AF/800AT	
			LTD: 2	LTD: 7	
		PD Coordination Only	STPU: 2.5	STPU: 4	

Fig. 9 Excerpt from Recommendations Tracking Log

VI. FIELD QA/QC CHECKS OF THE DRAWINGS, STUDY, AND LABELS

Aside from helping ensure that the recommended changes can be practically implemented, this final step also provides an opportunity for the field engineering and technical staff to get familiarity with the new one-lines, study, labels, and any changes to the site’s incident energy values. This familiarity will enhance safety for the workers as they will have a more complete understanding of the various assumptions and aspects of the study and model beyond simply referring to the applied arc flash and shock warning labels on the equipment. It will also provide an understanding of the various assumed operating modes, any compromises, assumptions made in the models or generation of the labels, internal equipment electrode/gap/enclosure details, their impacts upon the calculated incident energy values, limitations, gaps in information and analysis, where to find additional information when planning work tasks, PPE selection, background on the recommended protection settings changes, and coordination changes/limitations.

Knowledge of the studies, models, labels, assumptions, etc. will allow the field staff to better manage and steward the quality and accuracy of the studies over time for each site. A flowchart and explanation of the QA/QC process is shown in Appendix A.

VII. CONCLUSIONS

When performing electrical power system studies, there are different challenges that require using engineering judgement and proper documentation on occurrences. There are many aspects to consider for the different tasks that make up the complete study. For existing facilities, a field observation is highly desired to ensure that the one-line drawings match the equipment identification and name plate data. In most cases, not all items are able to be field verified, therefore, engineering judgement needs to be applied when information is missing or not readily available. In some applications, there could be multiple energy sources inside the same equipment and those instances needed to be evaluated.

It is also very important to have a proper QA/QC program in place, such as a system developed that documents the electrical study labels and the equipment where the label needs to be applied. Field implementation of the electrical study results, including the development or utilization of a field quality assurance/quality check (QA/QC) checklist, which would be reviewed to verify which results have been completed or which ones are outstanding.

VIII. ACKNOWLEDGEMENTS

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IX. REFERENCES

[1] IEEE 1584-2018, September 2018, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, New York, NY: IEEE.

[2] NFPA 70, *2020 National Electrical Code*, Quincy, MA: NFPA.

[3] NFPA 70E, *Standard for Electrical Safety in the Workplace*, Section 130.5(G), pg. 70E-26, 2021, NFPA.

[4] CSA Z462, *Workplace Electrical Safety*, Section 4.3.5.6.2, pg. 62, 2021, CSA Group.

[5] IEEE STD 141-1993, *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants*, New York, NY: IEEE.

X. VITAE

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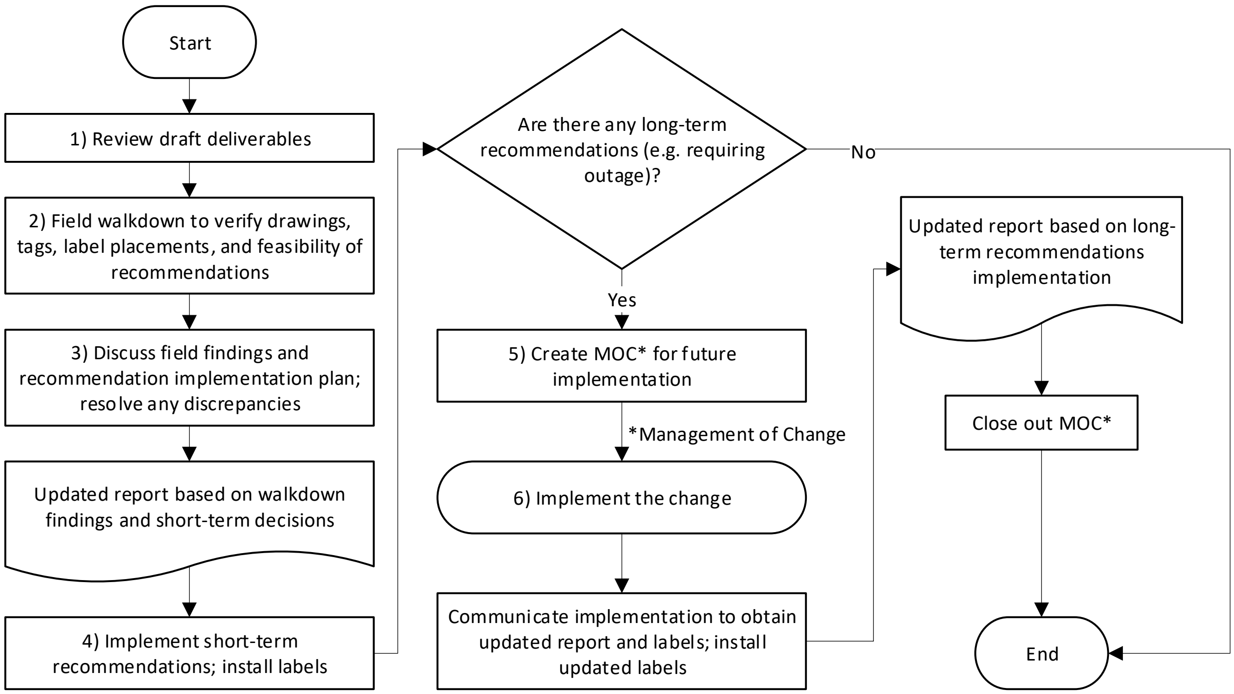
APPENDIX A
QA/QC PROCESS FLOWCHART



The field QA/QC check typically consists of the following steps:

1) Review the study, model, labels and any assumptions, recommendations, supporting information, equipment configurations, etc. by site/field engineering and site technical personnel. This can be done in real time with the engineering consultant who prepared the model and study, or it can be performed asynchronously with feedback and Q and A with the consultant.
2) Physically walk down the equipment at the site with the electrical one-line drawings, study, and preliminary printouts of labels in order to field verify the correctness of the one-line drawings, study, recommendations, and labels. Various detailed checks are made at this time and can include, but are not limited to:
   a) Correctness of one-line drawings/studies/labels against actual equipment layout/elevation drawings, settings, ratings, topology, supplied and connected equipment, location, tag names, descriptions, etc. One important check is to make sure that the tag names and descriptions of the equipment are consistent on the one-line drawing, the study, the label, and on the physical equipment (to reduce the chances of worker error).
   b) Verify that the recommended changes to breakers, fuses, relays, or other equipment is correctly conveyed in the consultant's documents and can actually be implemented on the equipment (for example: breaker trip settings can actually be changed as recommended in the study – the study's recommended new trip settings and the actual physical trip settings available and marked on the breaker actually match, and/or the breaker and its trip unit and available settings/curves are as described in the study).
   c) Where more complex changes are recommended (for example, replacing obsolete or under-rated equipment), then investigate, at least on a preliminary basis, the impacts and feasibility of implementing the changes. If rating plugs, breakers, fuses, or other components must be changed, then assess how easy it will be to do this, discuss any planned changes and needs for equipment outages with operations and other stakeholders to confirm feasibility, timelines, etc. For equipment in service, settings changes may introduce the risk of unplanned trips of the breakers in case the settings are done incorrectly. It may be wise to perform settings changes when the facility is de-energized for other reasons to reduce the chances of an accidental trip and its resulting operational impacts.
   d) Verify the exact placement of the actual arc flash label vs. the original temporary placeholder label – is the description of the equipment the label applies to, as well as other label content, valid and understandable by the workers who will be referring to it when doing the work? For example, if a label is intended to apply to more than one enclosure or MCC section or set of buckets – is it clear that it does so based on label content and placement? Have a worker act as a set of "cold eyes" to review the placement of the label and its content to make sure that the label is effective and the risk of misinterpretation is minimized when referred to, by itself, during some future work tasks. Some labels may apply to specific operating modes only, some may apply to single pieces of equipment or multiple pieces of equipment, some

may have maintenance mode switches affecting the incident energies and arc flash boundaries, some pieces of equipment may have labels on the front, back, and sides, etc.

e) If possible, and there are no issues, implement any changes, print and install arc flash and shock warning labels during this initial walk-down phase. See also point 4 below.

3) Document/log all findings/changes from the field QA/QC review and communicate these back to the engineering consultant performing the modeling and studies. If there are any errors in, or differences between, the one-line drawings, model, labels, etc. originally provided by the consultant and what the field needs or finds, review these and resolve them. Accuracy and correctness in the equipment, one-line drawings, models, studies, and labels are important for the safety of the workers. If there are any original recommendations that are questionable or infeasible, revise the recommendations accordingly or at least determine if there is an alternative approach or at least a partial implementation which can still improve worker safety (for example, if a trip setting cannot be adjusted down without causing nuisance trips for the equipment, perhaps a slightly higher setting than originally recommended, with a slightly higher incident energy can be used as long as the workers will still have sufficiently rated arc flash PPE). It may be necessary to revise the model and study accordingly based on the field's feedback in order to accurately represent the final recommendations and field implementation, and this final revision may then serve as the final record copy of the model/study/single line, etc. Note that, as previously described in this paper, it is convenient for everyone to have a single recommendations table near the beginning of the study which can be quickly and easily found by the workers when performing the field walk-down and changes review. This same table will also serve as a convenient record of all final changes recommended/implemented in the record copy of the study.
4) Once the field findings and one-lines, model, study, and labels are reconciled, proceed to implement the changes in the field (if not already done). This step may be completed during the original walk-down phase, or simultaneously/concurrently with the update to the one-line drawings, model, study, etc. in order to confirm that the actual changes can/have been successfully implemented. Printing and issuing the actual arc flash and shock warning labels can be performed at this time as well and placed on the equipment. If there are older label versions still present on the equipment, these must be removed or completely covered over in order to avoid confusing the workers.
5) If the owner has a Management of Change (MOC) process, or managed database of critical life safety settings for breakers, fuses, relays, and other protective devices, use those administrative systems to keep track of the pending and actual changes, for both immediate changes and longer term or future planned changes. These administrative MOC systems should require periodic reviews and status/progress updates, along with signoffs by proper engineering and operations authorities, to make sure that the recommended changes are implemented. Also, interim measures (for example, worker awareness training, restricted work tasks, special procedures, and temporary use of higher rated arc flash PPE) may need to be put into place until the final changes have been implemented.
6) Follow up on, track, and implement any longer term or future scheduled final changes necessary to complete the implementation of the recommended changes. Sometimes these final changes may be months or years after the final study is issued due to operational constraints or availability of equipment, parts, or personnel.

ONGOING LIFE CYCLE MANAGEMENT OF ARC FLASH STUDIES AND MODELS

Dedicated program management is required for the arc flash incident energy analysis studies for more than 140 sites, and numerous other support facilities and buildings. Therefore, there needs to be a systematic and organized approach with respect to stewarding these studies to always make sure that the latest models, studies, field collection data, utility data, and vendor/manufacturing data is always available to support the workers and consultants involved in updating these studies. Various changes frequently occur which can involve these models, studies, drawings, labels including:

1) Regular 5-year update cycles for all studies in order to keep them current.
2) Various brownfield capital projects of various sizes and complexity for various facilities (including controls changes or equipment changes).
3) Facility operational mode changes, sometimes associated with equipment changes, sometimes not.
4) Ongoing greenfield facility/study additions.
5) Changes to codes, standards, and industry best practices necessitating revisions to existing studies or implementing interim measures. Note: for example, there is a need to consider interim measures to accommodate potential increased incident energy values for certain electrode configurations per the new IEEE 1584-2018 methodology [1], while waiting for studies to reach their 5-year cutoff or any project driven updates.
6) Changes or corrections to engineering analysis software.
7) Changes to engineering consultant organizations used and their various methodologies/approaches.
8) Latest changes to engineering practice driven by new research and peer reviewed articles.
9) Identification of and need to correct errors in past studies.
10) Inadvertent loss of study or model files.
11) Acquisition of facilities from third parties.
12) Changes to internal safety practices and arc flash incident energy analysis study standards.

13) Changes to utility system configuration affecting short circuit capacities, various system impedances, and operating modes/regimens on the utility system. Updates should be done if there are any known utility changes in the systems supporting the facility (may not be readily known in all cases), and at least once every 5 years. [3] [4]
14) Changes or corrections to manufacturer's specifications and equipment parameters for existing equipment, possibly discovered through manufacturer testing or required equipment revisions.

To manage all of these changes, the numbers of sites, and the sheer volume of activity, it is essential that a robust database and arc flash study management process be established to accept new studies, manage the update of existing studies, and ensure that the latest and most accurate information is always available for personnel in the field. Aspects of this database include:

1) Implementation and communication of an up-to-date arc flash incident energy analysis technical specification to ensure ongoing study accuracy, correctness, and quality. This specification should also include special emphasis on usability for the field personnel, and substantial efforts to introduce design for safety elements into the systems, equipment, settings, etc. Full disclosure of all engineering assumptions must be provided.
2) Embedded safety-by-design elements in engineering design standards and equipment specifications, to ensure that all new equipment have these elements included from the beginning.
3) A regimented set of requirements and work flow process for all consultants and projects performing arc flash incident energy analysis studies including: predefined turnover of all field data collected, utility, generator, solar panel and other power source data collected, copies of relevant manuals/drawings, indexed and easily referenced picture database, study documents (simplified consistent standardized template formats preferred), and all model/library files and custom application files, supplemental calculation spreadsheets, notes on all engineering assumptions pertaining to equipment configuration, electrodes, gaps, enclosure sizes, etc. Turnover of all the data is essential for ongoing support and management of the studies, and for use in any potential incident investigations.
4) Requirement for initial study scoping meetings, and periodic review meetings with the consultant at key points such as pre-field data collection, pre-modeling, post-modeling/first study draft, field review stage, and final issue stage. These meetings must be fully documented.
5) QA/QC spot checks of all the turned over information to ensure consistency, correct methodology and reasonableness of assumptions, and a full documentation trail.
6) Dedicated, experienced internal personnel to manage and support the scoping, guidance, and review of the consultants' work on an ongoing basis, and ensure alignment with the latest codes, standards, and industry practices. These internal technical personnel act as custodians of the information, as well as supporting consultants, internal engineering and projects, operations, and electrical maintenance groups.
7) Establishment of a secure database for storage of all sites' full arc flash study data, with easy navigation and access. Access privileges controlled and assigned per the needs of the organization.
8) Continuous and ongoing status reporting to sponsoring management for the above infrastructure and supports, as well as for ongoing budgetary and resourcing support for ongoing study updates across the organization's facilities. This requires senior management agreement and support for the importance of these studies for worker safety, and sometimes efforts need to be made to ensure ongoing alignment with the corporation's arc flash incident energy analysis study programs and technical requirements.

APPENDIX B
ARC FLASH LABEL AND PLACEHOLDER LABEL INSTRUCTIONS

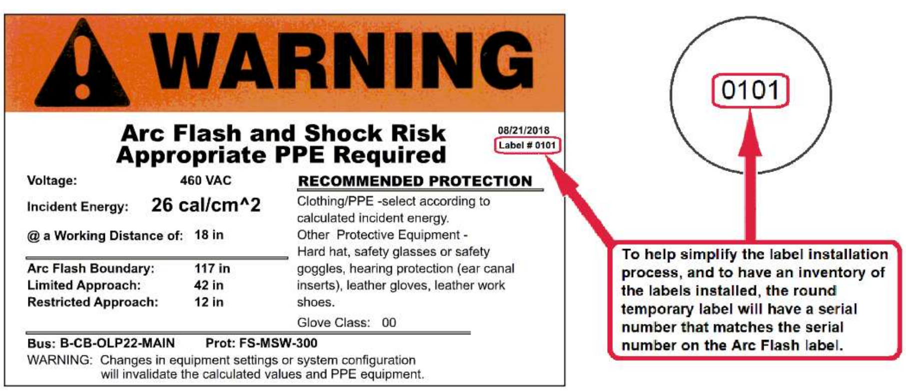


Fig. 10 Placeholder Label and Arc Flash Label