Data Collection for an Arc Flash Hazard Study

CHAPTER 07

Arc-flash calculations are only as accurate as the model used as the basis of the calculations. Creating an accurate model requires collection of system data, either from existing documentation, field data collection, or more commonly, a combination of the two. Data collection and system modeling can require a considerable amount of time and effort—often more than actually performing the study. Any existing documentation or previous studies should be used to reduce the amount of time required for field data collection.

This document is a reprint of Chapter 7 of the Practical Solution Guide to Arc Flash Hazards book. You can download the entire free book at www.easypower.com/arcflashbook.

Introduction

Like any other project, data collection requires prior planning and should take into consideration the following concerns.

- What existing documents are available and how accurate are these documents?
- What is the scope of the study and how much of the system is included?
- Where are the interfaces between the system to be evaluated and the local utility or other entities?
- How much field data collection will be required and how will it be done?
- What are the responsibilities of the facility team versus the study team?
- How will the safety of the data collection team be addressed?

Based on the answers to these questions, the arc-flash risk assessment may need to be broken up into different phases. It might be better to collect data and build the one-line model from the medium and high voltage distribution downstream to the individual low voltage substations, collecting data for each feeder serving a switchboard, MCC and panelboard. Typically, arc-flash incident energies are higher at these locations than in other low voltage equipment further downstream in the system. After the intermediate study has been completed, then additional data may be collected and added to the EasyPower model to perform the arc-flash risk assessment. The scope of the study and the best approach to sequencing the work should be discussed with the facility staff and well-documented.

The scheduling and sequencing of data collection will depend on who will be doing the on-site work: a member of plant staff, a contracted individual who is normally on-site, or a consultant or contracted individual who has traveled to the site. If site personnel will be responsible for data collection, it will be important to communicate clearly regarding what data is required.

Obviously, the amount of time required for data collection depends on many factors, including:

- Size and complexity of the electrical system.
- Physical access constraints.
- Quality of data available from existing documentation.
- Number of people available to do the data collection.

The following steps can serve as rough mileposts for the data collection process, recognizing that every facility and situation will have unique aspects.

1. Review available documentation, especially one-line diagrams and physical layout drawings, including site plans. In many cases, these may be available electronically, but for older facilities, hard copy documents and drawings may be the only option. It is also important to capture notes and red-lines on existing drawings that indicate changes to the system subsequent to the original document. Even if the documentation is not totally current or needs field verification, review of this information can save hours of on-site field work. For arc-flash studies, the following documents can be helpful:
   - Existing one-line diagrams.
   - Previous electrical system studies, including short circuit, coordination, and any previous arc-flash studies.
2. Discuss with site staff any known issues with the documentation and system changes that they are aware of. Also, make note of any previous system studies that may be available along with shop drawings, bills of materials, and test reports.
3. If possible, based on the available documentation, develop a preliminary one-line diagram to get an overall understanding of the system, making note of additional data that will be required. This preliminary one-line diagram is helpful for identifying missing data and developing the necessary data collection forms where field data collection is necessary.
4. For larger systems, it may be helpful to create a rough physical map or layout of the key components including transformers, sources, switchgear/switchboards, and distribution points (MCCs, panels, etc.). A simple hand drawing will do for a start. Plant engineers and electricians typically have knowledge of the layout of the system. Consultants can obtain information from plant personnel or existing drawings to create this rough map.
5. Based on the preliminary one-line diagram and the physical layout sketch, develop a list of data needed and plan for on-site data collection. Data collection forms or templates can be helpful for keeping track of details, organizing information, and saving time. A few example templates are included later in this chapter in the Data Collection Template section.
6. Coordinate with the plant personnel for the site visit. If data collection is to be done by persons not familiar with the facility, it is necessary to have a site electrician assist with the location of all equipment. In some cases, it may not be possible to obtain the required data if it becomes necessary to open some equipment covers, as that may require de-energization and interfere with the plant operation. The information may be obtained later during scheduled maintenance or reasonable assumptions may be made. Any assumptions made should be noted in the study report.
7. Use a digital camera if possible. The pictures often reveal more information than what you record in your notes. If you have difficulty understanding any of

the equipment data, you can obtain help from experienced people using the picture.

8. Most equipment has nameplates that show the equipment ratings. Note the details from the nameplates and take a photo if possible.
9. For equipment with adjustable settings, note the range of available settings and the current setting. The status of switching devices should also be noted (open or closed).
10. Create a one-line diagram showing all the equipment such as utility connections, transformers, cables, switches, circuit breakers, fuses, loads, switchgear, etc. Make sure that their interconnection is correctly represented in the drawing. Mark each equipment item with the ID names and enter the relevant data. Commercial power system software like EasyPower can create one-line diagrams, store all the necessary equipment data, and perform arc-flash risk assessment. ID names are also important for placing arc-flash labels in the appropriate locations after the equipment incident energy has been determined.
11. The more knowledge the electrician (plant personnel) has of the facility, the better the final model will be. You may need to consult with several plant individuals before you understand or gather data you need.
12. If you have information from previous studies with recommended settings or drawings, be sure to verify the data. The facility may not have been updated after the previous study, fuses may have been changed, or the instantaneous trip functions may have been adjusted due to nuisance tripping.
13. Before beginning data collection, understand the purpose and scope of the data collection. What kind of study are you performing and what areas of the facility must be modeled?
14. Strive to collect all necessary data while in a particular area to minimize the need for additional site visits or data requests. Take photographs of equipment whenever possible.
15. The electrical safety of the data collection team is the first priority and needs to be included in a comprehensive Job Safety Plan document for the data collection project.

This book is focused on performing arc-flash hazard assessment studies, but if other studies could be performed in the future using the one-line model developed for the arc-flash study, you may want to consider collecting additional information while performing this study. The data to be collected as described in this chapter will allow for short circuit analysis, protective device coordination, and arc-flash studies

Items Useful for Data Collection

The following material and items may be required or useful while collecting power system data:

- A signed energized electrical work permit if required.
- Clipboard, pencils, highlighter, graph paper, or notebook.
- Existing one-line diagrams.
- Facility drawings.
- Templates for protective device settings.
- Tables of protective device settings (such as relay setting sheets).
- A non-conductive flashlight.
- A non-conductive mirror and handle, so that you can view difficult locations and avoid blind reaching.
- A digital camera or cell phone camera.
- A laptop or tablet for entering information directly into EasyPower.

Safety Tips for Data Collection

Although not comprehensive, keep the following tips in mind:

- Whenever possible, perform data collection on de-energized equipment unless it is not feasible.
- Avoid opening equipment doors on energized equipment unless truly necessary. Electrician opening the door should be wearing appropriate PPE. Everyone else should be behind the arc-flash boundary and the Restricted Approach Boundary while the door is opened.
- Remain behind the Restricted Approach Boundary at all times while collecting data.
- Some data may not be safely obtainable through field inspection. If the equipment is energized and all the necessary information cannot be obtained, perform data collection during a scheduled shutdown, or obtain data from shop drawings, test reports, or other documentation. In some cases, reasonable assumptions must be made. Any assumptions should be noted in the report. Do not take unnecessary risks when collecting data.
- Electrical hazards such as shock and arc flash are not the only hazards that

exist during data collection. Follow all site safety policies regarding the use of ladders and lifts for work above the floor and use fall protection as required. If necessary, shutdown and lockout conveyors or other moving equipment.

- Watch for loose screws, bolts, or other metallic parts.
- Do not touch any equipment unless necessary and avoid leaning or sitting on equipment.
- Keep track of all tools, cameras, phones, and backpacks, and avoid leaving things behind. All equipment should be left in the same condition as found.
- Do not open any enclosure doors or covers without permission or without proper PPE. It is preferable for the plant maintenance staff to open and close all equipment doors.

Estimations and Assumptions

During data collection, there may be some estimations or assumptions that must be made when information is not available or cannot be safely obtained.

Be sure to document all assumptions in the report in case any questions or issues should arise in the future.

Common Items that may need to be assumed or estimated:

- Missing or unreadable nameplates. Review existing drawings or data sheets to obtain available information. If drawings or data sheets are unavailable, base your assumptions on similar equipment installed close by or at the same time as the equipment you are documenting.
- Conductor length. It can be difficult to determine cable, busway, and transmission line length due to walls, high ceilings, or difficulty tracking conduit or cable tray. Length estimates within 10% of the actual length are generally acceptable. Do not forget the vertical portions of the cable and conduit runs. The importance of cable length on short circuit calculations increases as the voltage level decreases. For example, ignoring a 50-foot conductor at 13.8 kV may not affect calculations, while ignoring a 50-foot conductor at 480 V or 208 V may affect calculations more significantly. 208 V arc-flash calculations are highly sensitive to cable length data.
- For molded case circuit breakers (MCCBs) with an unknown instantaneous setting, assume it is at the maximum available setting. This will always be conservative for arc-flash calculations.
- For MCCs and panelboards, it may not be necessary to collect data and model every feeder completely. If no arc-flash label is needed at the downstream

equipment, it may be sufficient to record the type of load present. If labeling is not required at individual motors, the motor loads fed from each MCC may be grouped based on size. For a typical MCC, the minimum data required is listed below.

- Main breaker/fuse.
- Largest feeder breaker/fuse and load/motor information.
- Protective device and conductor information for any equipment that needs to be modeled for arc-flash analysis, such as a sub-panel or sub-MCC.
- Group total <50hp motor horsepower.
- Group total >50hp motor horsepower.

This grouping of motor load is only applicable for constant-speed motors. Motors fed from adjustable frequency drives do not generally contribute fault current so must be modeled separately. Also, any downstream equipment that requires an arc-flash calculation and label must be included in the model explicitly.

A template showing the minimum recommended MCC information is shown in the Data Collection Template section.

- For long runs of bus duct with numerous taps, it may be time consuming to collect data for all the equipment served from the bus taps. If time or access to the bus plugs are an issue, consider collecting feeder data for an assortment of bus plug sizes along the length of the bus duct. For example, if a bus plug is 200 feet in length, you might consider collecting data at the beginning (0 feet), middle (100 feet) and end (200 feet), for different bus plug sizes (30 A, 100 A, 200 A). Then in the EasyPower software, model a bus at each of the three bus duct locations and add the generic feeder data for each of the bus plug sizes at each bus. An example is shown in the following figure. As long as the conductor length is similar, using the generic arc-flash incident energy should be sufficient. If the length is much longer, then these cases should be modeled individually. Also, it is recommended that any bus plugs 400A or larger should be modeled individually. Since an EasyPower bus is required to show taps from the bus duct, it is reasonable to group the taps at buses instead of creating a bus for each tap. It is important to get an approximation of the total length of the bus duct and model the bus duct system such that the modeled length is roughly equal to the actual length.

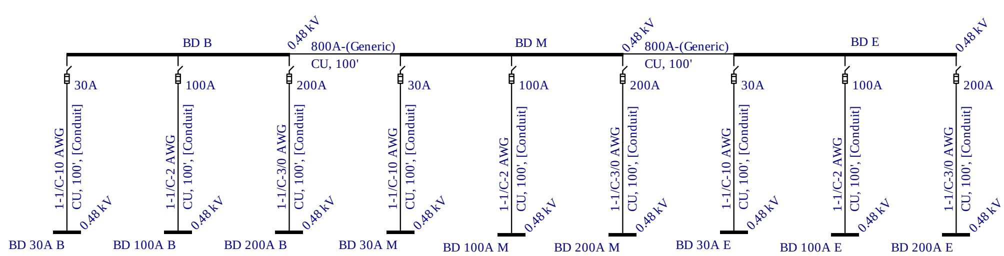


Figure 7.1: Generic Bus Duct Example

- There are books and papers from manufacturers available that provide typical data for equipment. A book that has quality data that can be used as estimations is A Practical Guide to Short-Circuit Calculations by Conrad St. Pierre. The book can be purchased by contacting EasyPower.

Time Current Curves and Arc Duration

In certain situations, the published manufacturer's time-current curves do not provide sufficient information to determine a precise arc time. EasyPower determines the duration of the arcs based on the following IEEE 1584-2018 recommendations:

- Where the current-limiting fuse equations are not applicable or not used, the manufacturer's time-current curve information is used. If the manufacturer's curve includes both minimum melt and total clearing time curves, the total clearing time is used as the arc time. If the manufacturer's curve has only the average melt time, an additional 10% of the average melt time plus 0.004 seconds is added to that time to determine the arc time. If the total clearing time at the arcing fault current is less than 10 milliseconds, use 0.01 seconds for the time.
- For relays operating in their instantaneous region, a minimum time of 16 milliseconds (on 60 Hz systems) is used for the relay trip time. The breaker clearing time is always added to this relay time for medium and high-voltage circuit breakers. This default minimum time of 16 ms can be adjusted by the user in the Advanced section of the Arc Flash Options.

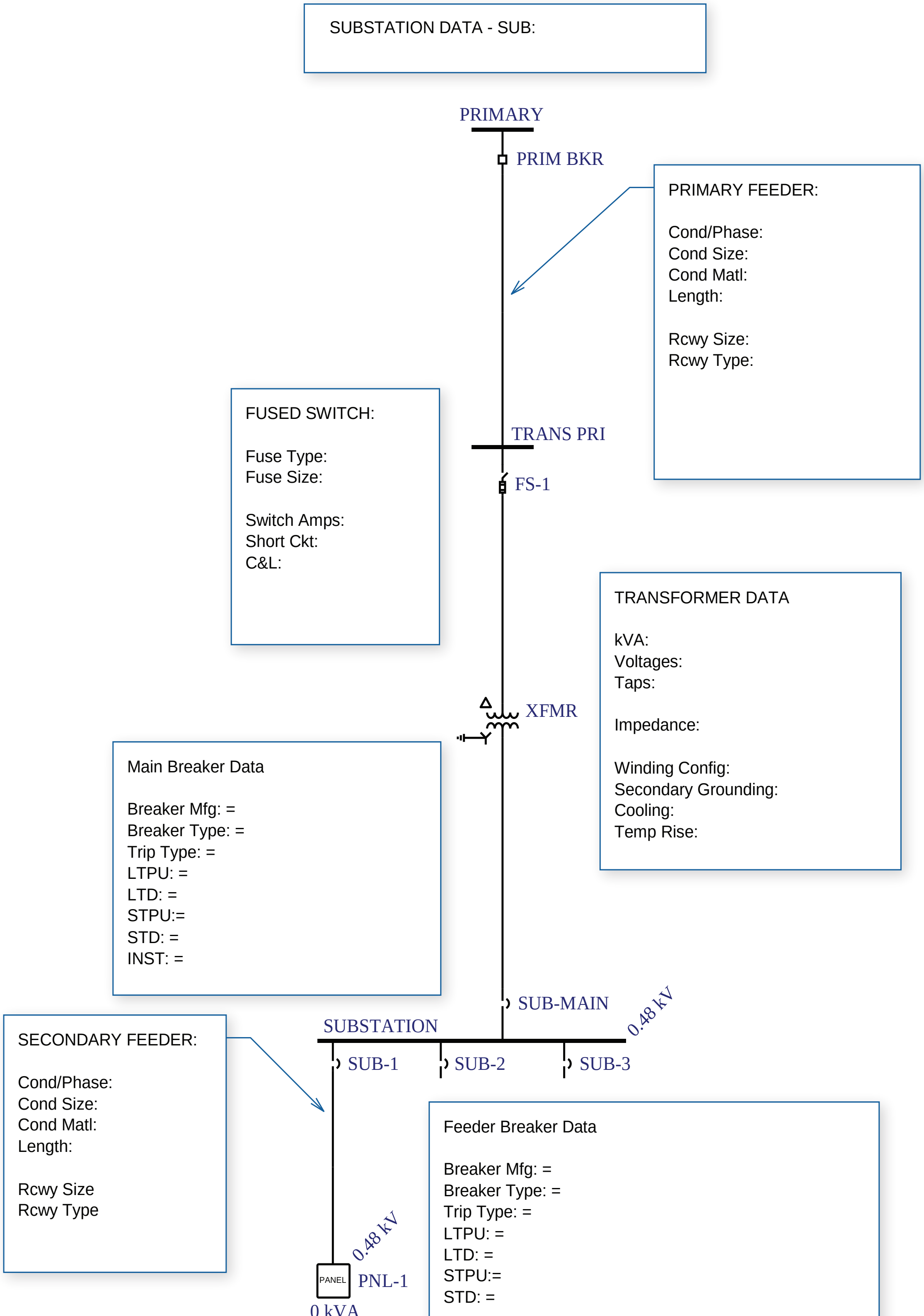
For situations where the arc time cannot be determined based on time-current curves, EasyPower provides for use of a "User-Defined" arc time that can be set in the arc-flash options for any bus. An example of the use of a User-Defined time is to provide an arc time for equipment protected by differential relays or arc-flash detection relays.

Data Collection Templates

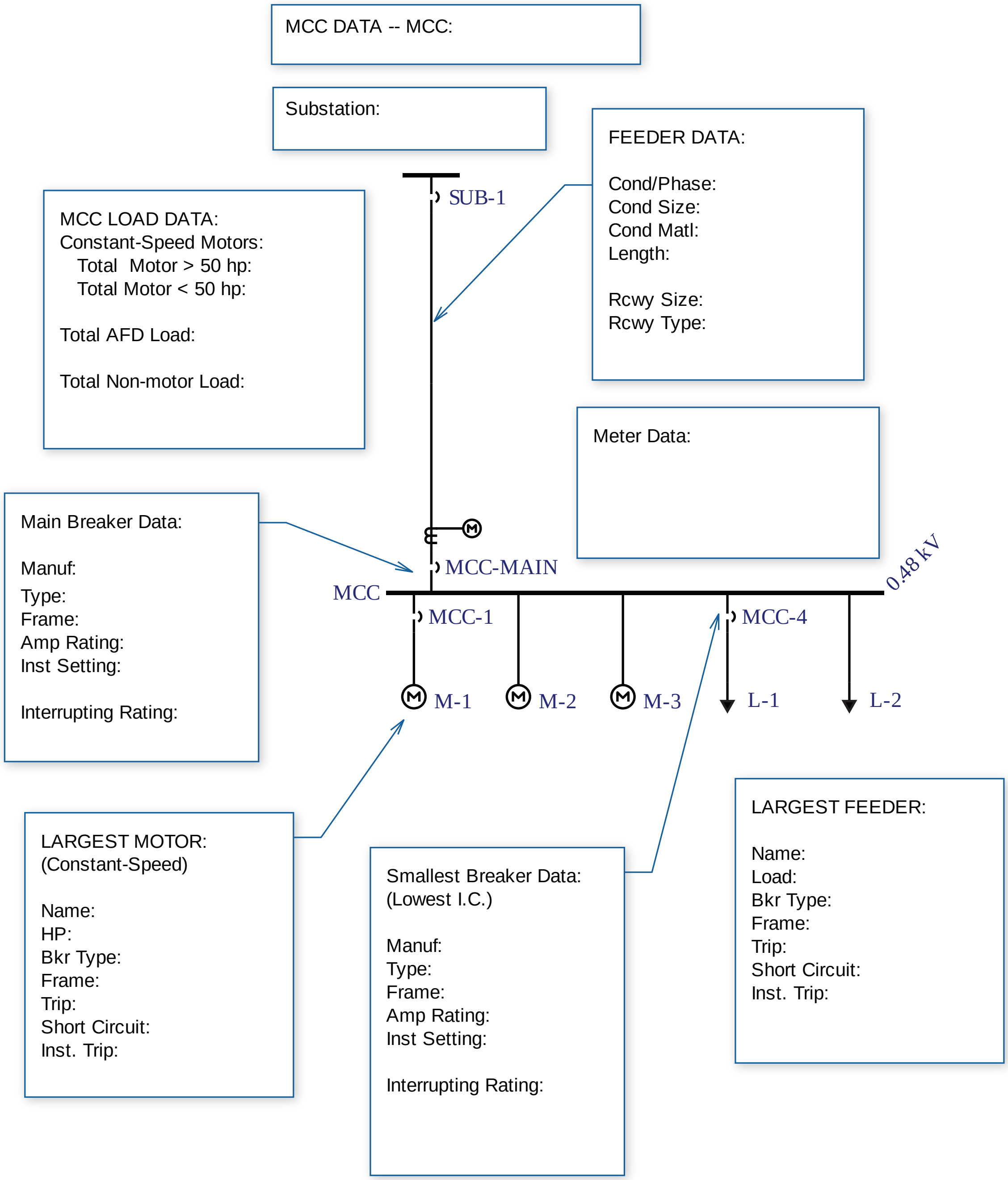
In this section, sample templates are provided for a low-voltage substation and an MCC that show the type of data collection that is generally required. These templates may be used directly or as a guide for creating your own templates. It also may be more convenient for you to create spreadsheets instead of using one-lines.

The third template is for data collection of low voltage power circuit breakers with associated trip units. The template includes all the different device types and settings that are required to properly model the breaker and trip units in the EasyPower software. For other types of protective devices, data collection templates may be created based on the software requirements.

Substation Data Collection Template



MCC Data Collection Template



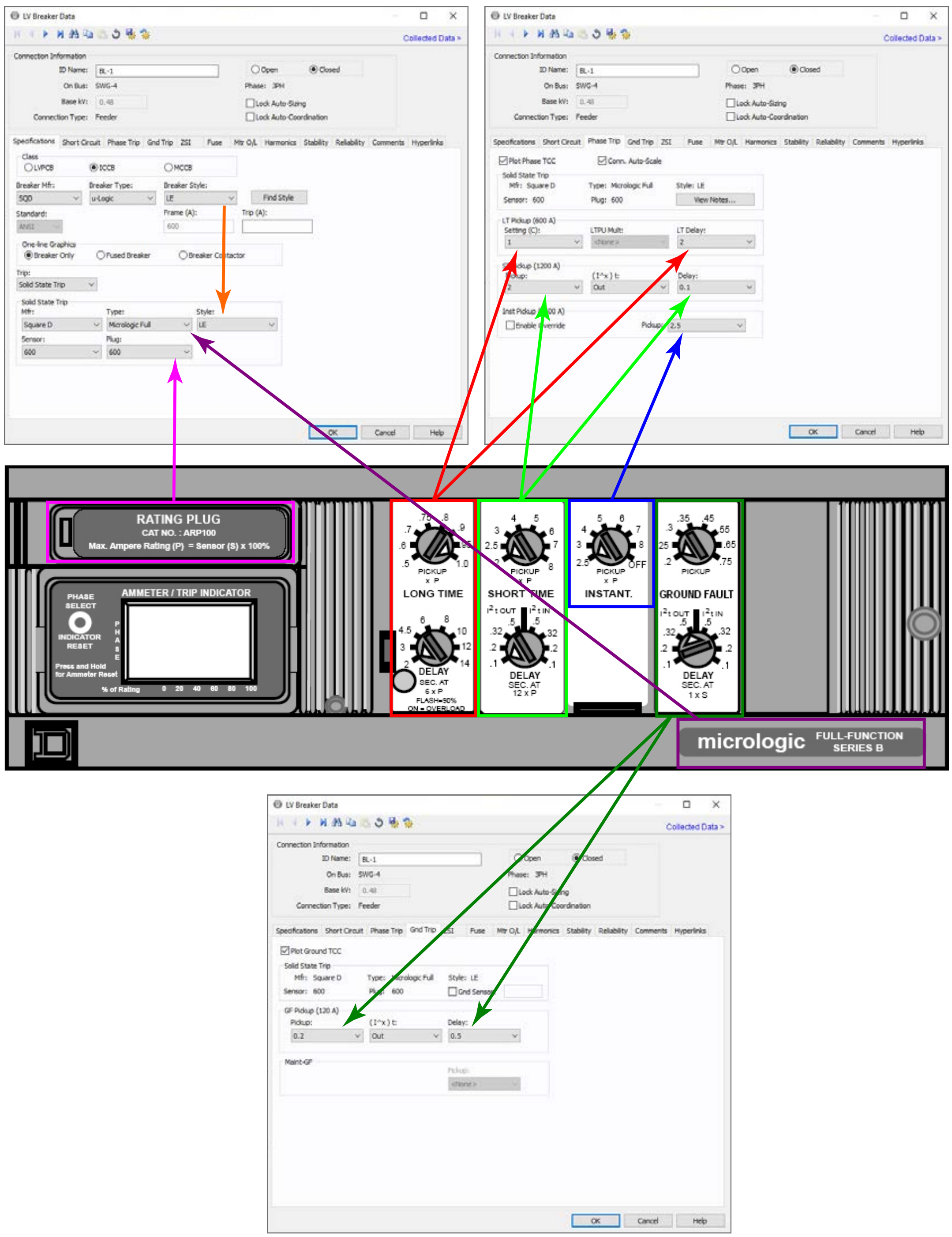
Form for Low Voltage Breaker with Trip Units

Breaker ID	Breaker Mfr/Type	Frame Size / Sensor	Trip Unit Mfr/Type	Plug Rating	Long Pickup	Long Time Delay	Short Pickup	Short Time Delay	I^2T	Inst. Pickup	Ground Pickup	Ground Time Delay	Interupting Rating	Comments

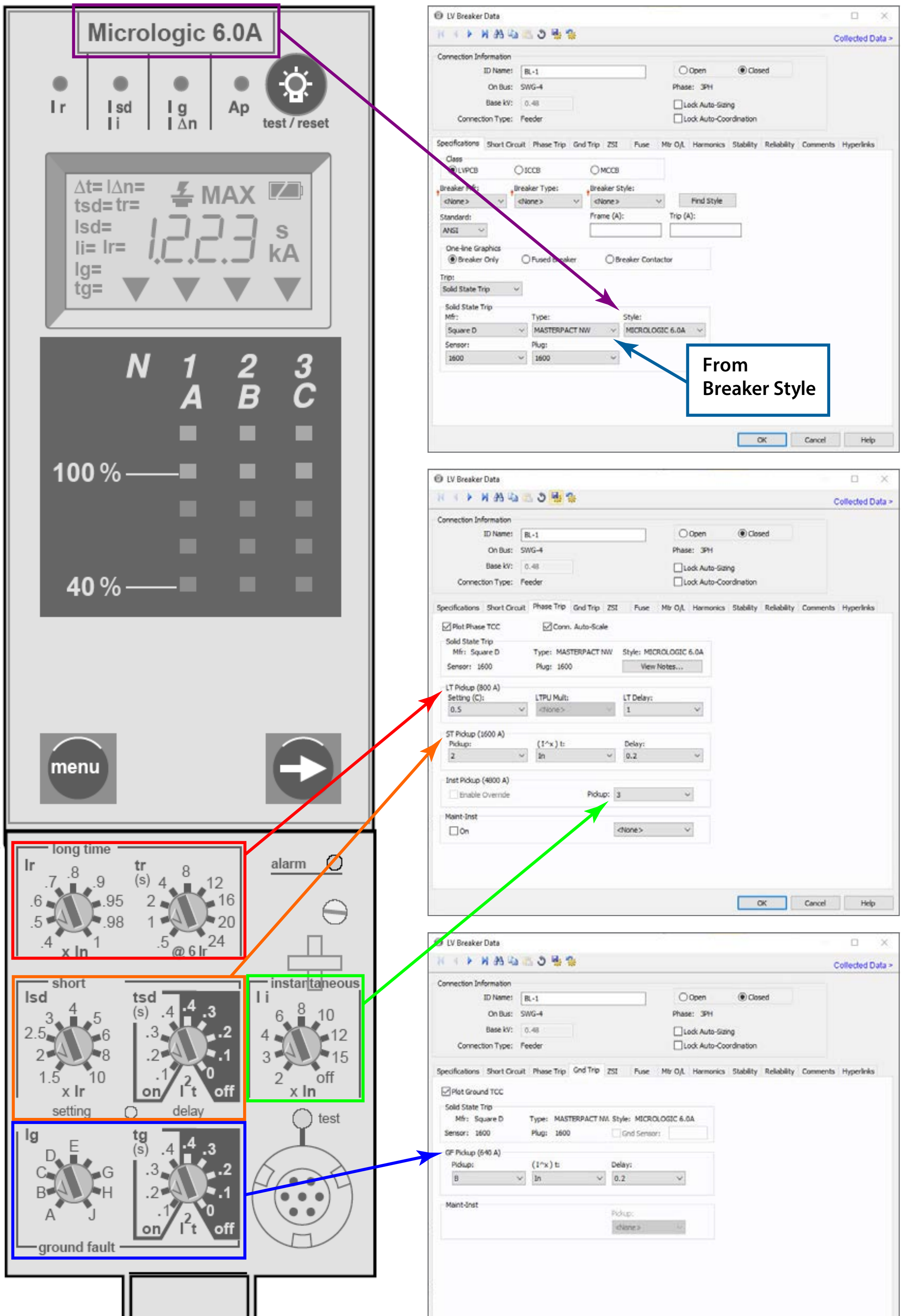
Equipment Name Plates and EasyPower Data

In this section, you will see how to use name plates to collect data as well as where it will be placed in EasyPower power system software, for later arc flash analysis.

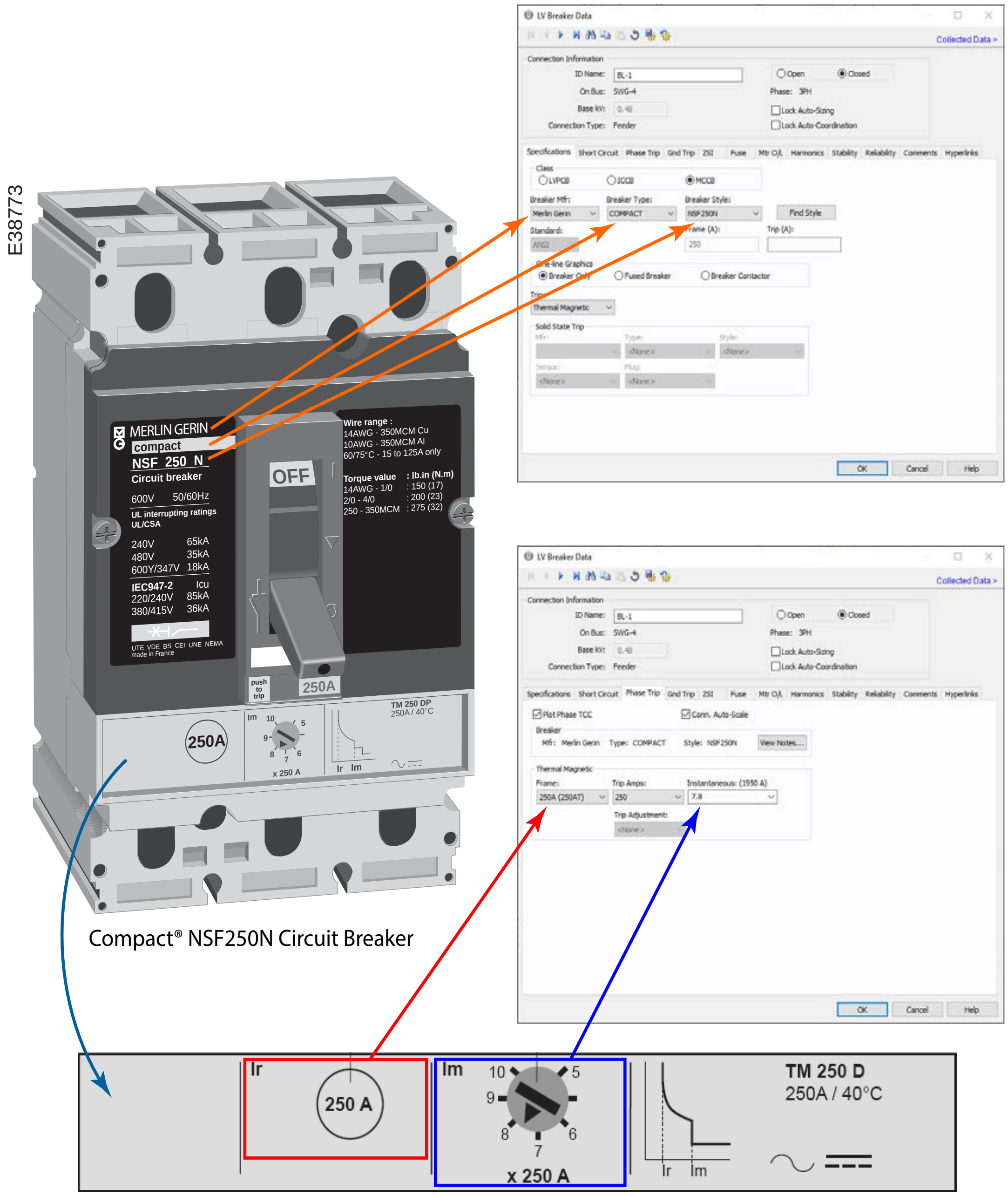
Solid State Trip (Example A)



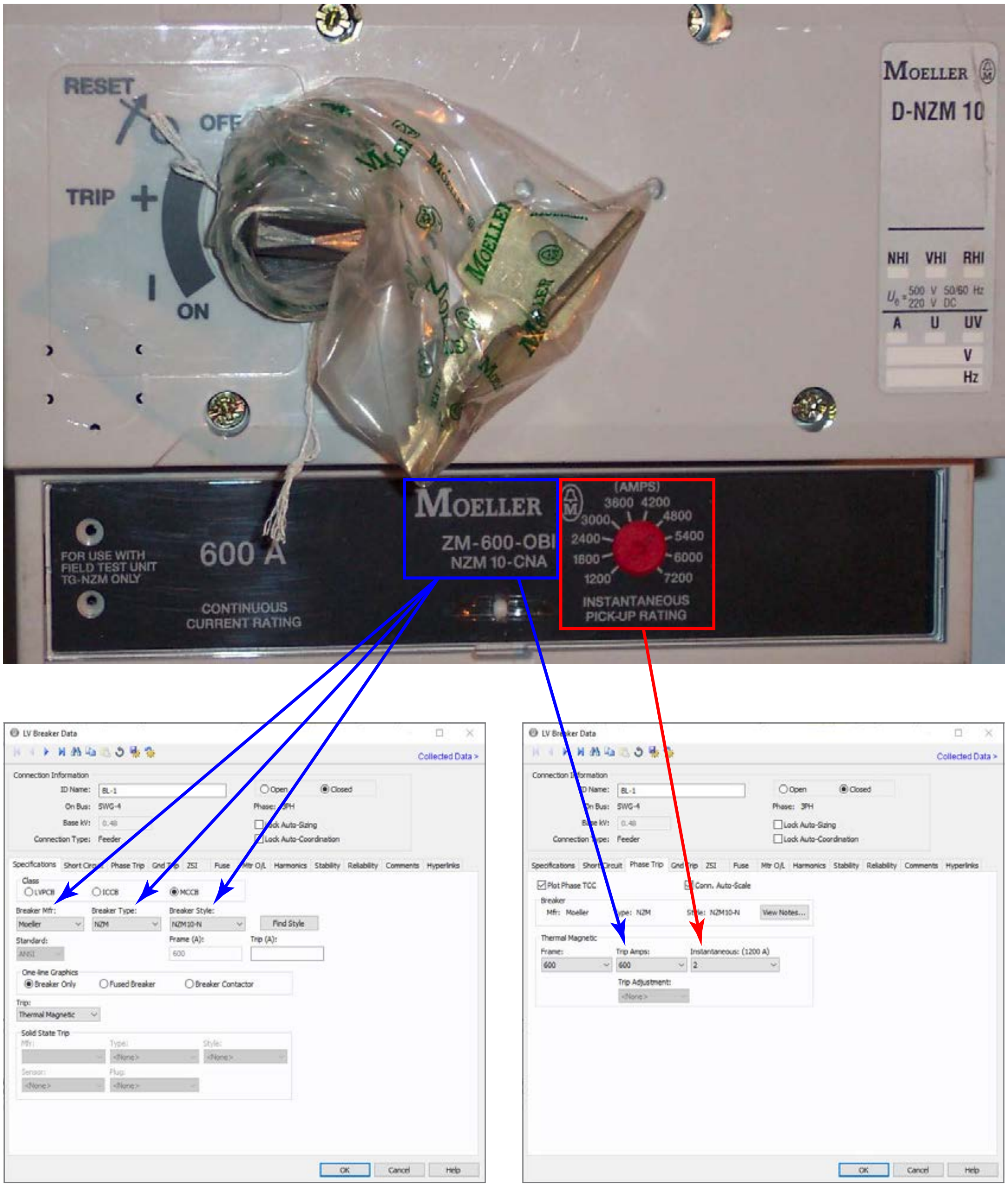
Solid State Trip (Example B)



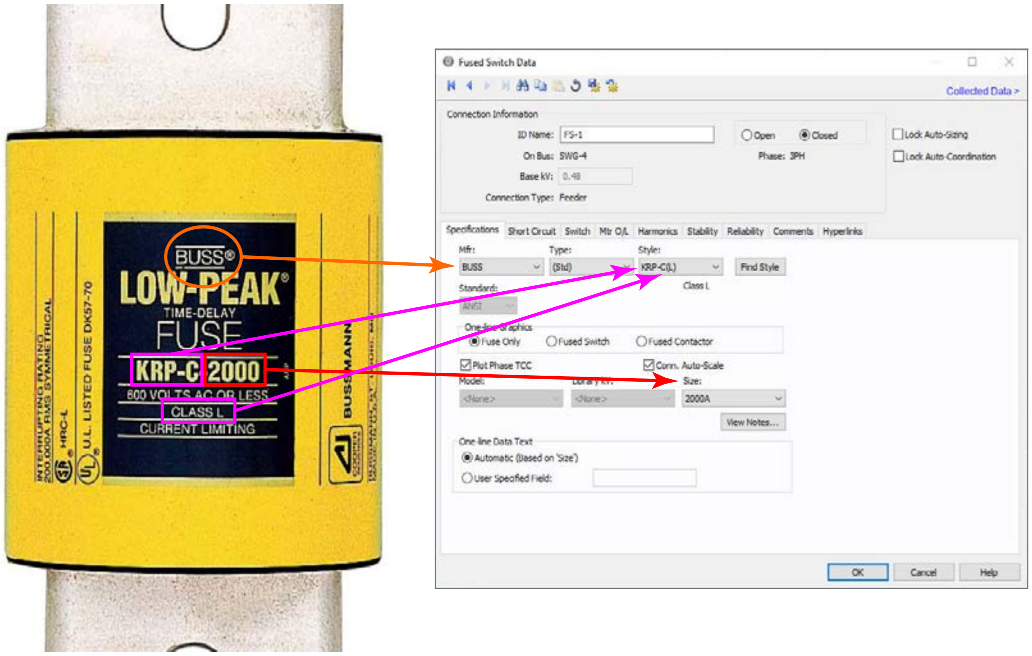
Thermal Magnetic Breaker (Example A)



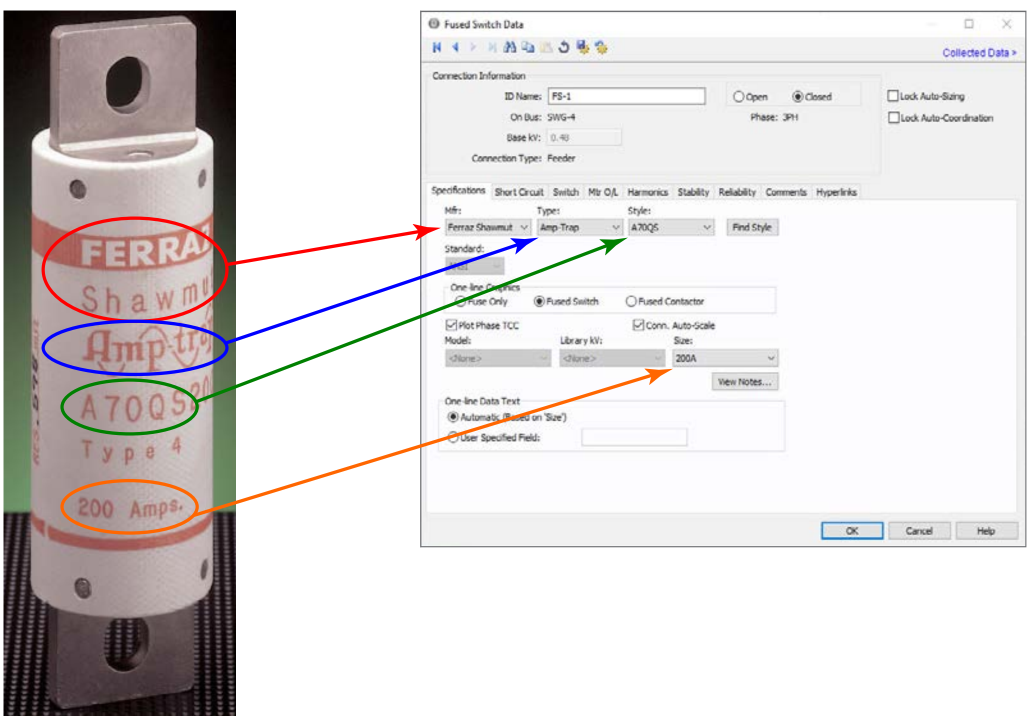
Thermal Magnetic Breaker (Example B)



Low Voltage Fuse (Example A)

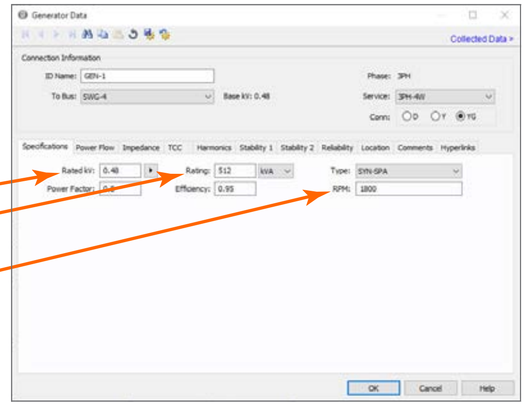


Low Voltage Fuse (Example B)



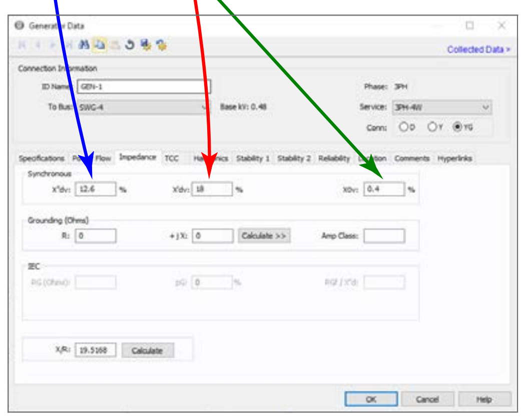
Generator (Example A)

Model	S4
Power Factor	0.8
kVA	512
kW	410
RPM	1800

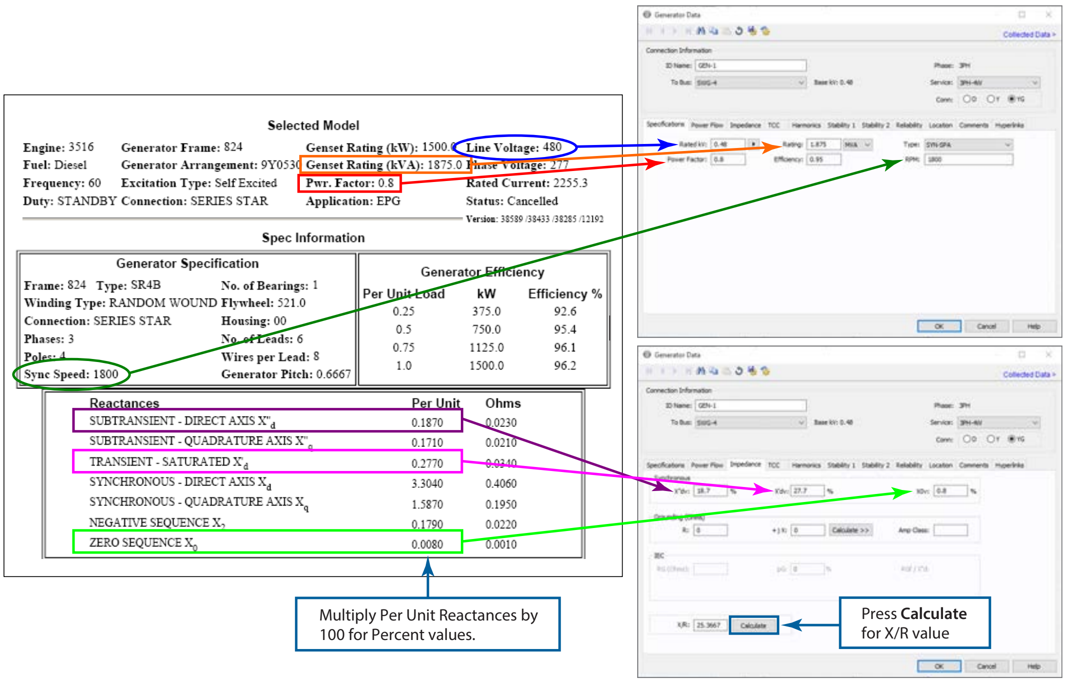


Reactances Class H / 480 V - Time constants (ms)

		VS2	S4	S5	M7	M8	L9	L9 (6w.)
Kcc	Short-circuit ratio	0,36	0,36	0,32	0,40	0,31	0,35	0,36
Xd	Direct axis synchro. reactance unsaturated	349	335	373	319	376	344	338
Xq	Quadra axis synchro. reactance unsaturated	209	201	223	191	225	206	203
T'do	Open circuit time constant	1738	1855	1855	1930	1958	1997	1997
X'd	Direct axis transient reactance saturated	20,1	18	20,1	16,5	19,2	17,2	16,9
T'd	Short circuit transient time constant	100	100	100	100	100	100	100
X"d	Direct axis subtransient reactance saturated	14,1	12,6	14	11,6	13,4	11,8	12,1
T"d	Subtransient time constant	10	10	10	10	10	10	10
X"q	Quadra. axis subtransient reactance saturated	19,1	16,9	18,8	15,3	17,8	15,6	15,8
Xo	Zero sequence reactance unsaturated	0,1	0,4	0,1	0,1	0,9	0,9	0,4
X2	Negative sequence reactance saturated	16,6	14,8	16,5	13,5	15,6	13,7	14
Ta	Armature time constant	15	15	15	15	15	15	15



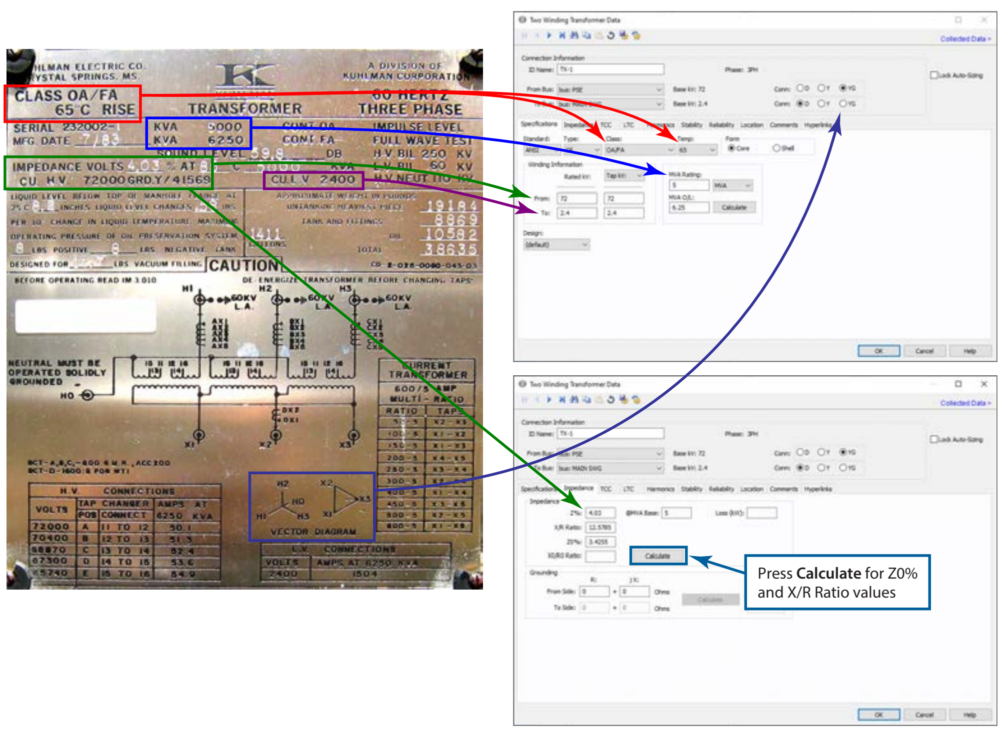
Generator (Example B)



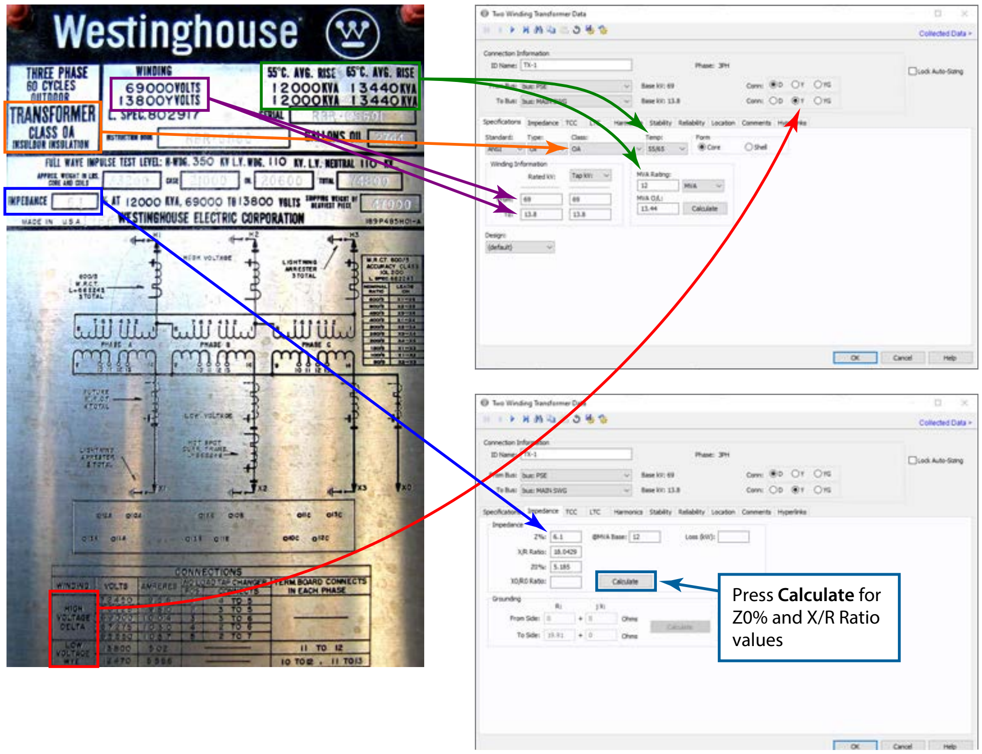
Per Unit Load	kW	Efficiency %
0.25	375.0	92.6
0.5	750.0	95.4
0.75	1125.0	96.1
1.0	1500.0	96.2

Reactances	Per Unit	Ohms
SUBTRANSIENT - DIRECT AXIS X''_d	0.1870	0.0230
SUBTRANSIENT - QUADRATURE AXIS X''_q	0.1710	0.0210
TRANSIENT - SATURATED X'_d	0.2770	0.0340
SYNCHRONOUS - DIRECT AXIS X_d	3.3040	0.4060
SYNCHRONOUS - QUADRATURE AXIS X_q	1.5870	0.1950
NEGATIVE SEQUENCE X_2	0.1790	0.0220
ZERO SEQUENCE X_0	0.0080	0.0010

Transformer (Example A)



Transformer (Example B)



Medium Voltage/High Voltage Breaker