



SUBSTATION DRAWINGS

WILL THEY BE READY WHEN YOU NEED THEM MOST?

Part 4 in a 4-Part Series on Protection Engineering

It is very easy to forget about your substation drawings when everything is running smoothly. Perhaps you believe scheduled equipment replacements or routine system maintenance is the only time you truly need them. While these are major reasons, they are not the only reasons. Therefore, it is critical to have updated substation drawings, and to have them accurately reflect what exists in the field.

So, what risks do you face if your drawings are not up to date, or if you don't have them at all? There are many, including but not limited to: incurring excess costs, increasing customer complaints, and experiencing complicated and serious problems. In extreme cases, serious injury or death of workers may even occur. As it pertains to sustained operation of your substation, you are facing the following risks:

1. Outage-Related Time and

Pressure Problems: Let's say that a piece of equipment fails and customers are out of power. You quickly arrange for replacement equipment and it promptly arrives on-site. Now you're ready to go to work. Are your drawings ready?

- You may know where the control cables landed on the failed equipment, but the replacement equipment isn't the exact same model, and its terminals are laid out differently. With up-to-date drawings, this information is easy to find.
- You may know which panel the other end of the cable terminates, however,

you are unsure of the specific terminals, or how the relays are connected to them. This information should be available on your drawings.

Without updated drawings, you don't know how to hook up the new equipment. In the meantime, worker hours are racking up, costs are increasing, you can't estimate a time to completion, and customers continue complaining about "the lights being out."

While all outages cannot be avoided, having accurate drawings will position you to expeditiously address the outages when they do occur. They give you a leg-up on providing a speedy outage restoration.

2. Outage-Related Safety Problems:

Worker safety is of the utmost importance to everyone. Wiring with out-of-date drawings, or no drawings at all poses extreme risk to your field personnel. It puts everyone on site in danger, and may lead serious injury or death.

Without proper drawings, employees will assume that the existing protection scheme is correct. This may not be the case. The following situations may occur:

- They may make updates that result in additional problems. They may inadvertently introduce issues to the protection system. Upon re-energization, fuses may blow because the voltage transformer secondary may be inadvertently shorted, or a current transformer secondary may have been inadvertently left open. Additional outages may even occur.



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- Workers will have to guess how the wires are connected. If they guess wrong, they could be seriously injured - or worse.
- If they unknowingly have outdated drawings, it's could be even worse. They will assume that ALL the information is correct. They'll assume that they don't have to guess, and therefore will not be as cautious. They'll just perform their wiring and move on.

Safety side note: When a current transformer's primary circuit is energized, its secondary circuit should never, ever be open-circuited. The current transformer secondary circuit will drive current through whatever resistance there is, including an air gap. An open-circuit current transformer secondary will generate an extremely high voltage in an attempt to jump that gap, or in other words create an arc, in order to force current to flow. If you have a current transformer that is intended to be unused, short its secondary terminals and ground it, BEFORE its energized.

3. Switching Error Problems: If your one-line drawings aren't kept up-to-date, switching errors become more likely.

Ideally, one-line and three-line drawings should have breakers, reclosers, circuit switchers, switches, basically all substation equipment, labeled following your company's naming policy. It's more important to have the drawing labels exactly match the field equipment labels, rather than what the labels actually are. For example, a switch that is labeled 'SW123' should have a corresponding 'SW123' element on the drawing. If the labels and drawing designations don't

match up, then it may be difficult to identify the corresponding 'SW123' in the field. If the wrong switch is opened, you may have just turned the power off to some of your customers, or worse, endangered your lineman's safety.

4. Equipment Damage Cost

Problems: Using out-of-date drawings to perform any rewiring can also result in equipment damage. As noted earlier, if your linemen have no drawings, or inaccurate drawings, there is a risk of damage to voltage transformers, current transformers, breakers, reclosers, or another piece of equipment when the system is re-energized. This could result in more equipment replacement costs and longer power outages.

5. "Waiting Too Long" Cost

Problems: On a recent project, a municipal utility was replacing one of its substation transformers. Finley Engineering was contracted to provide the construction drawings for connecting the existing wiring to the new transformer. The cables were not only for DC control, but also for current transformer secondary circuits.

The other end of one of these cables was wired to a control house panel, where the transformer's protective relays resided. Finley Engineering requested both the schematic and panel connection diagrams, in order to use them for reference and to make the necessary updates. The utility responded that they didn't have any drawings. The utility did not know how the protective relay panel, or any of the other panels in the control house, were connected to anything.



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Finley Engineering proposed to create a new set of schematic and connection drawings. However, this would require re-creating every drawing from scratch, meaning that every wire and every cable would have to be traced by hand - an extremely labor-intensive and expensive process. If the utility had simply kept their drawing information up-to-date from the start, the whole project would have been much easier to implement.

6. “Blame Game” Problems: Finally, if accidents, injuries, excessive costs, or repair delays occur because of less-than-ideal drawings, questions WILL be asked. “How could this happen?”, “Who is responsible?”, “Who is guilty?”, or “Who is it that will get the blame from senior management?” are some of the questions you could be faced with.

To avoid this situation, it is imperative to prevent these issues before they occur. Providing a set of accurate, up-to-date drawings for your substations goes a long way in avoiding these problems.

To get started, review your current drawing set. Here are a few different drawing types that you should have readily available for quick and ready reference.

One-Line Diagrams:

- Provide a general overview of the entire substation, including transformers, switchers, breakers, etc.
- Have switch numbers and breaker labels that match the actual equipment labels in the field.
- Provide a high-level overview of the relays and protection equipment.
- Include general information, as well as some specific equipment information. This could mean including manufacturer names, model numbers, serial

numbers, current and voltage ratings, etc.

Three-Line (or AC Elementary) Diagrams:

- Show individual phases.
- Indicate instrument transformers connections, with panel terminations called out.
- Call out relay connection points.

Connection Diagrams:

- Show point-to-point wiring and intra-panel wiring for every piece of panel, or cabinet, equipment.
- Show connection points to each relay or device inside the cabinet, or panel.
- Show cabling for inter-panel connections to other cabinets or field devices, such as transformers, breakers, or instrument transformers.

Schematic Diagrams:

- Show how the protection system is powered.
- Show the protection system logic. In other words, they map the interconnection between the relays and the equipment.
- Show what equipment operates when specific relays operate.

Nameplate Drawings:

- Are copies of the nameplates for all of the major substation equipment.

Manufacturer’s Drawings:

- These are the original drawings from the equipment manufacturer.
- Nice to have, however, they must be REDRAWN for YOUR specific system and YOUR specific connections.
- They are useful for troubleshooting when quick responses and safety are important.



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It is also very important to have more than one copy available, or to have a maintained soft copy available through modeling software.

- Have a full set of easily-accessible substation drawings kept on-site, so that personnel can quickly reference them as needed.
- Have a duplicate set in your main office. These are your backup set, in the event that the drawings at the substation are damaged or lost.

Also keep in mind that your drawings and diagrams should always incorporate any updates. Over time, even the most accurate and most comprehensive drawings will fall out-of-date if even minor wiring changes are made without proper documentation. This can result in huge drawing discrepancies and complicate troubleshooting, potentially creating a dangerous and costly situation.

You don't need to have a specific, regimented schedule for updating drawings. Rather, drawings should be updated when ANY change is made in any DC control circuit, current circuit, or voltage circuit. This could be for any piece of substation equipment, such as breakers, reclosers, transformers, etc. A single wiring change may seem to only affect a single drawing, but frequently it affects more than one drawing, and may possibly affect several. Also make sure that all copies, whether on-site or at the main office, have the same updates made. Doing this will eliminate the confusion of, "Which drawing is the right one?"

Conclusion:

It does take time, effort, and commitment to keep your drawings up to date, but you will thank yourself later - especially when you are under pressure to "get the lights back on."

Finley Engineering can help you with this process. We specialize in reviewing, updating, and maintaining drawings as designs change, or we can create a new set of drawings if needed. We can assist you with your drawing sets so that you and your employees can be as fully prepared as possible when problems occur. It is well worth the time and effort to address your NOW when your system is operating correctly. Identify issues during an emergency can lead to escalating costs, longer outages, and dissatisfied customers and senior managers, despite your frantic efforts to figure out what's wrong and what needs to be fixed.

Remember, if you don't have drawings, or do have them but don't keep them updated, you risk:

1. Outage-Related Time and Pressure Problems.
2. Outage-Related Safety Problems.
3. Switching Error Problems.
4. Equipment Damage Cost Problems.
5. "Waiting Too Long" Cost Problems.
6. "Blame Game" Problems.

Contact Finley Engineering to help reduce this risk.

We specialize in this area and we are glad to assist you. 800-225-9716