



FINDING COMMON GROUND



**Our goal is to bring Eaton's customers,
experts, and switchgear data to a
common ground by facilitating better
communication and collaboration.**

Executive Summary

Spring 2017

Electricians, electrical engineers, facility managers, and Eaton experts all interact differently with switchgear, equipment used to protect and isolate electrical components. Through our research, we identified a need to bring these people and switchgear data to a common ground by facilitating better communication and collaboration.

About the MHCI capstone project

We are Team Spark, students from the Masters of Human-Computer Interaction program at Carnegie Mellon University. In January, our client, Eaton Corporation, had given us the long-term goal of envisioning the future of interacting with switchgear. For the spring semester, our primary objective was to understand the day-to-day work processes, goals, frustrations, and needs of the primary users interacting directly or indirectly with switchgear, and use the insights derived from the research to come up with possible visions that we could pursue. In this report, we discuss the insights that we uncovered, the process that we followed, and the design directions we intend to take during the second phase in summer.

Understanding the power domain

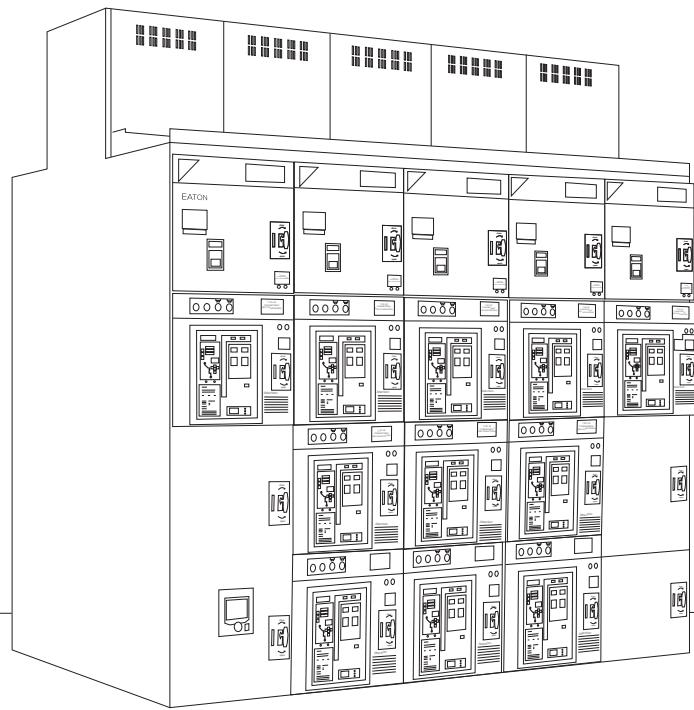
During our research, we conducted directed interviews with 17 different stakeholders including electricians, field service engineers, facilities managers, Customer Integrity Team members, and directors at Eaton. We then incorporated our findings and observations into an affinity diagram to derive insights and conducted a walk-the-wall session with the Eaton team to generate ideas and visions.

Exploring emerging technology

Additionally, we conducted secondary research and interviews to gather an understanding of how emerging technologies are used in analogous domains such as construction, medicine, data analytics, aviation, military, oil and gas, and steel industries to improve the experience of interacting with complex systems.

Bringing visions to life

On the basis of our research insights, we intend to design, prototype, test, and iterate on a set of selected visions over the summer semester. With these visions, we aim to help Eaton define a roadmap to stand out as an innovative player in the switchgear market.



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Investigating Power Management

Findings from primary research



To understand the power management domain, we interviewed the following 17 stakeholders:

Eaton Customers

- 2** Electricians
- 2** Electrical Supervisors
- 1** Electrical Engineer

Eaton Management

- 3** Field Service Engineers
- 1** Principal Engineer
- 1** Power Systems Automation Engineer
- 1** Customer Integrity Team Member
- 2** IT Directors
- 1** Marketing Manager

Analogous Domain Experts

Autodesk Research, IBM Watson, & M*Modal

**Switchgear can be considered
a fuse box but for large facilities.**



Demystifying Switchgear

Understanding the grey box

A fuse box for large facilities

A switchgear is essentially a combination of devices which protect the electrical installation of a large facility. It follows the same principles as fuse boxes in households—when there is an issue in the electrical circuit, it shuts the power. For instance, when there is a lightning strike, there could be tremendous levels of current flowing through the circuits. This could damage equipment connected to the power outlets. The switchgear ensures that these equipment remain protected by breaking the circuit (“tripping”) temporarily and stopping this massive surge of current from flowing.

More than a regular fuse box

Nonetheless, many factors set switchgear apart from normal fuse boxes. The current no longer amounts to a few hundred volts but can go above 20,000 volts. To cope with the increase in voltage, a larger, more sophisticated gear is required. The risk associated with switchgear also goes up exponentially, as there are major concerns about electrical explosions, called arc flash events. Uptime is very important, and stakes are high. Imagine the consequences if the intensive care unit of a hospital suddenly ran out of power.

Interacting with switchgear

Switchgear are large, complex, and hazardous. Understanding all of the functionalities requires experience and expertise. Devices within such as relays, meters, and breakers have different ways of functioning, different interfaces, and different versions. Each electrical installation is also different—hence each switchgear is designed differently. On top of this, risk of electrocution and arc flash makes the switchgear environment especially hazardous. All these various factors ultimately make interaction with switchgear a challenging experience and justifies the need for this interaction to be carefully designed.

Eaton's Customers

Electricians & Electrical Supervisors

Electricians and facility managers work in **high-risk and noisy environments** to keep power running safely in large buildings such as hospitals and universities. Eaton provides switchgear and services to these customers.

Steve, Electrician

Steve has been working as an electrician at a university for 16 years. He feels that he is responsible for keeping the place running, troubleshooting everyday problems quickly, and keeping everyone safe.

"Everyone wants to know when the power is coming back. How am I supposed to know if I have no idea what went wrong!"

- Electrical Supervisor

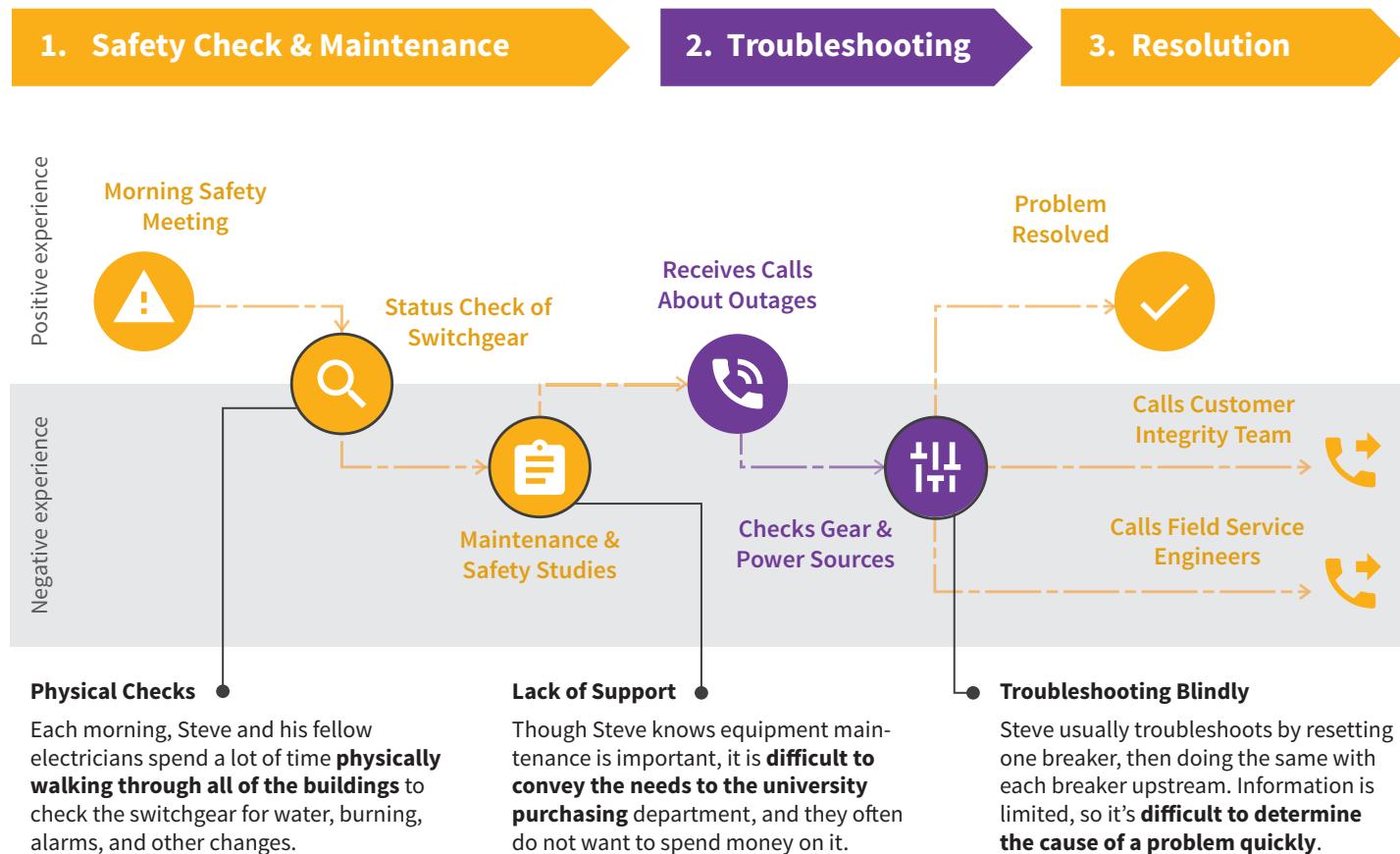


Andrew, Electrical Supervisor

Andrew is the electrical supervisor at a university. His primary goal is to prevent problems early on by ensuring the best equipment are installed and proper studies and inspections are done. He also keeps track of load balancing between various facilities at the university campus.



A Day in the Life of Electrician Steve



Off-Site Experts

Customer Integrity Team, Power Systems Automation Team

These experts answer questions and provide support to field service engineers working on-site, as well as facilities managers, electricians, and electrical supervisors troubleshooting problems with their switchgear. The **lack of spatial and visual information** makes the job challenging at times.

Tim, CIT Member

Tim, a member of the Customer Integrity Team (CIT), works with 3 other team members to support hundreds of thousands of switchgear across the world. He loves helping customers and engineers solve problems smoothly on the field.

"It would be most helpful to have the device right in front of me."

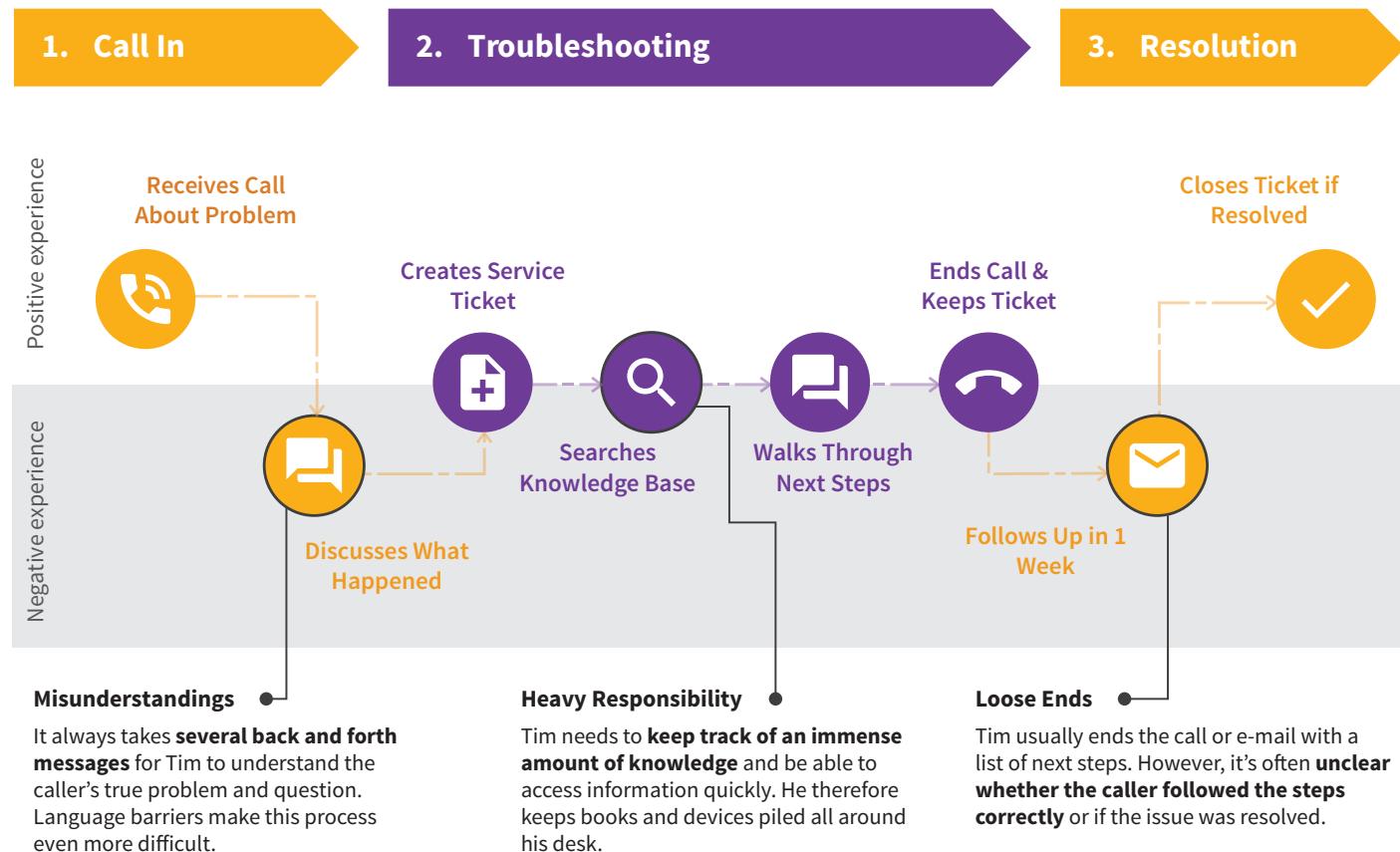
- CIT Member

Michael, PSA Engineer

Michael's background and passion lie in IT engineering. His goal is to ensure data about electrical equipment, represented by alarms or one-line diagrams, is communicated to customers in the form of actionable information.



A Day in the Life of CIT Member Tim



On-Site Experts

Field Service Engineers

These engineers are experts of electrical systems and travel to customer's facilities to provide hands-on installation, maintenance, and troubleshooting services. When opening up the switchgear, they must wear **personal protective equipment (PPE)**, cumbersome suits that protect them from injuries due to electrical hazards.

Brad, Senior Service Engineer

Brad's role is to install switchgear in new facilities, conduct maintenance tests, and help troubleshoot problems on-site. He enjoys his work because he loves problem solving. He values maintaining good relations with customers he's been dealing with for a long time.

"I wish the customers had the relevant manuals and drawings."

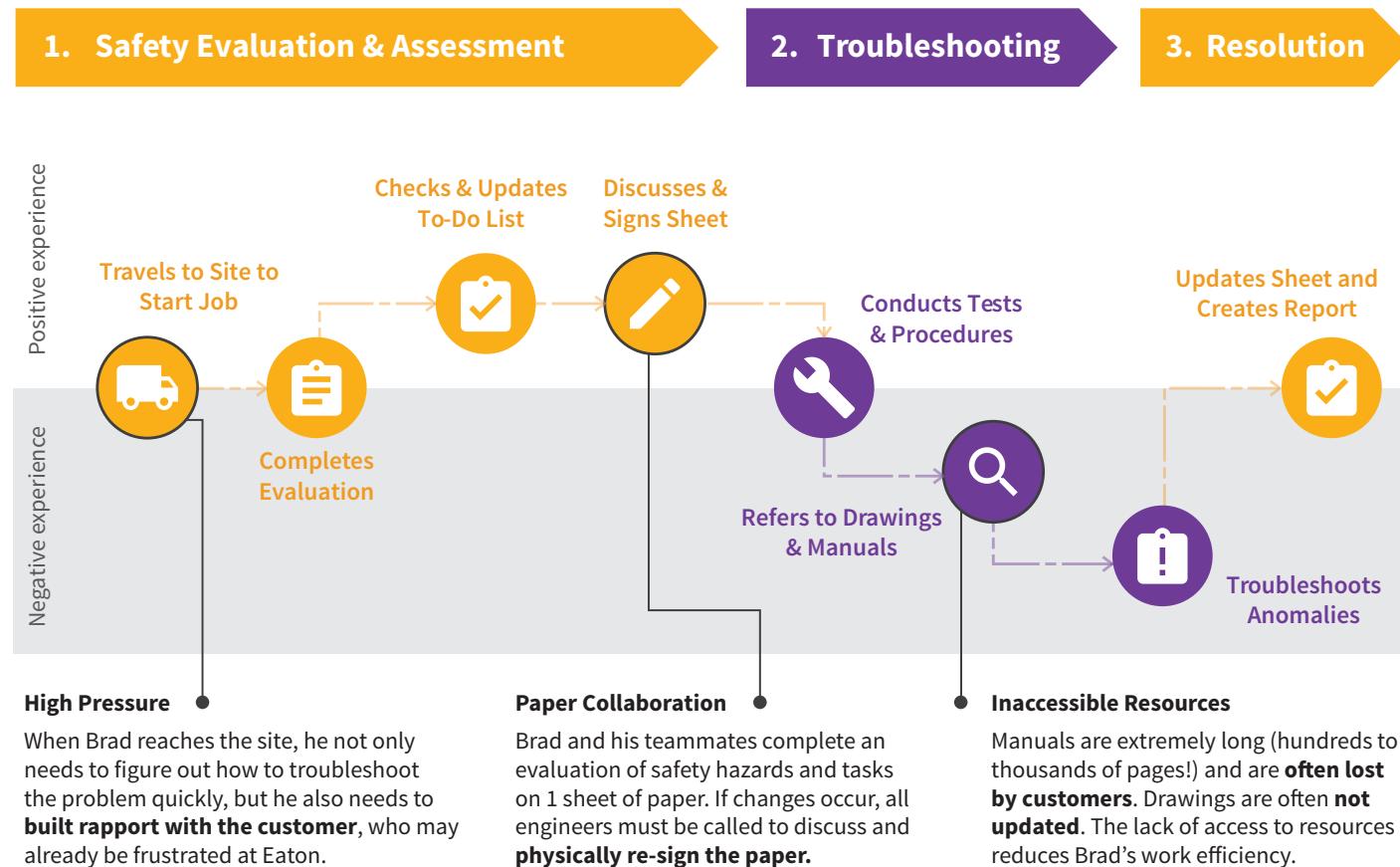
- Field Service Engineer

Shane, New Service Engineer

Shane joined Eaton as a service engineer a year ago. He underwent training in a controlled training environment and has shadowed his mentor for several months. He has now started working independently, which gets stressful at times as he is still getting used to it.



A Day in the Life of Service Engineer Brad



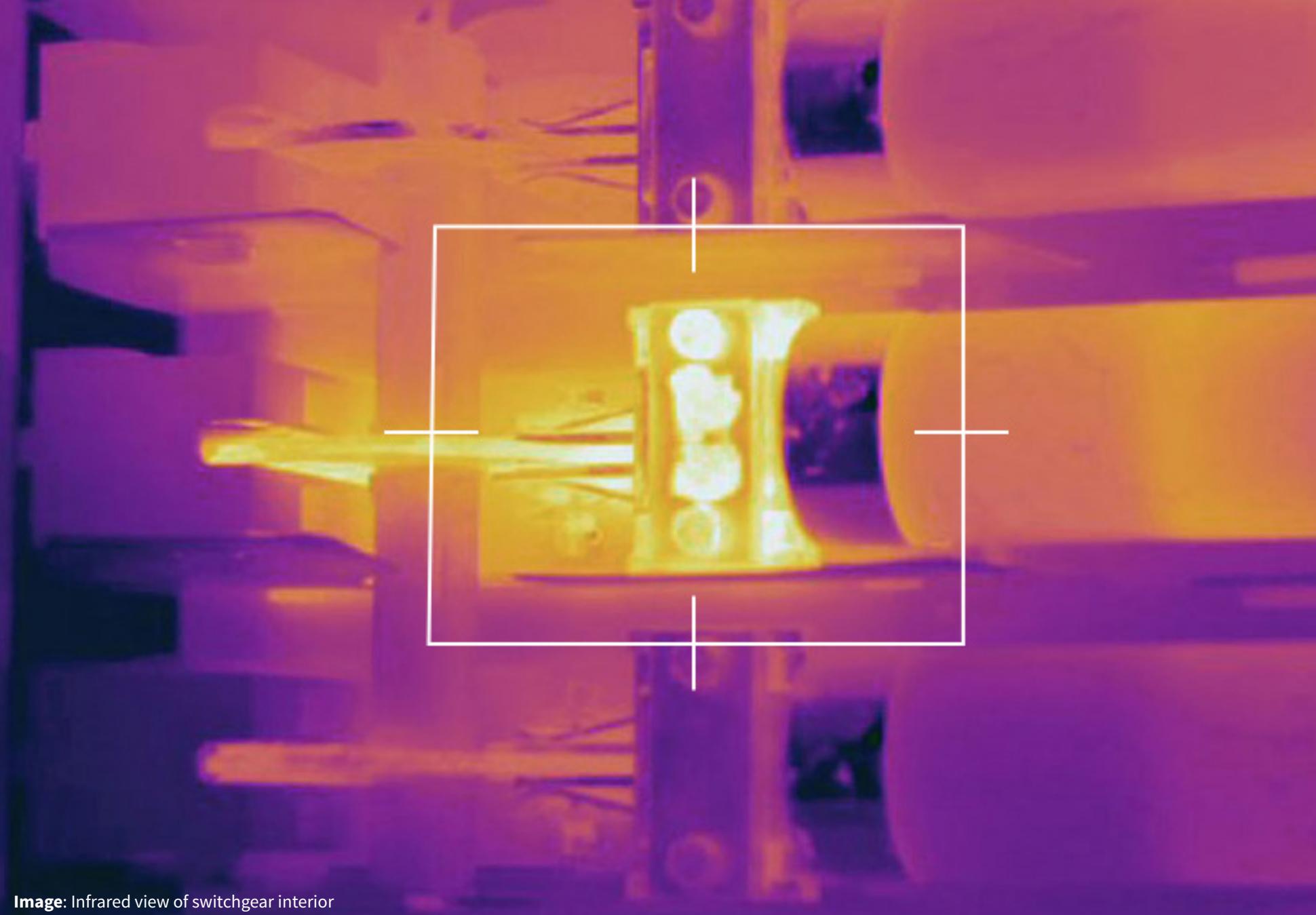


Image: Infrared view of switchgear interior

Locating Loose Connections

Insights from the field

1

Hazard labels are not enough to prevent **complacency** about workplace safety.

2

Examining switchgear is a **time-consuming** and **tedious** process for electricians.

3

Electricians need more **actionable** information from their switchgear.

4

Manuals are **too exhausting** to be useful, so electricians prefer to call Eaton directly.

5

Remote support is limited by the **lack of spatial and visual** information.



WARNING

EATON

Powering Business Worldwide

SHOCK & ARC FLASH HAZARD

Location: VCPW (Line Side)

Report #: TQSABC1234.1 Rev. 0

Issued: MAR-2014

NO LOCAL MAIN CONSIDERED FOR ARC FLASH CALCULATIONS.
UPSTREAM PROTECTIVE DEVICE APPLIES.

9' 9" **ARC FLASH BOUNDARY**

3.7 cal/cm² **CALCULATED INCIDENT ENERGY
AT 36" WORKING DISTANCE**

4,160 V Shock Hazard

Min. Glove Class: 1

Limited Approach Boundary: 6' - 0"
Restricted Approach Boundary: 2' - 2"
Prohibited Approach Boundary: 0' - 7"

"In this field, you can never be too safe."

- Electrician

Hazard labels are not enough to prevent complacency about workplace safety.

Though they understand the importance of safety, customers sometimes do not conduct studies or wear personal protective equipment due to **inconvenience, time, and cost.**

OSHA safety standards

Since 1974, the Occupational Safety and Health Administration (OSHA) has mandated that employees must wear appropriate personal protective equipment (PPE) near electrical hazards to protect them from injury and death. However, conducting arc flash studies to determine the correct PPE requires hiring contractors, costs tens of thousands of dollars, and is highly invasive and time-consuming, taking up to around a year.

Lack of adherence to safety

Though electricians and supervisors understand the importance of safety, many older facilities do not actually conduct the studies due to the factors described. Additionally, some facility electricians choose to not wear PPE while working on switchgear because they are hot and cumbersome.

"I distribute articles and videos on safety in my morning meetings. I tell them 'be safe'."

- Electrical Supervisor

Story from the Field

Five years ago, Harold, an experienced electrician, met with a tragic death due to electrocution. While working on a switchgear at a university, he became complacent and did not feel the need to wear PPE, which resulted in this avoidable accident. Harold was extremely proficient at his job and highly experienced. The incident remains etched in the minds of many electricians in the city, reminding them that one can never be too safe in this field.

*"We have 19
electricians who
walk around
the facility on a
regular basis to
check if every-
thing is alright."*

- Electrical Supervisor



Examining switchgear is a time-consuming and tedious process for electricians.

While looking for obvious sources of problems, electricians physically **walk through their facility to discover them.**

Signals to watch for

Through experience, electricians know that risk of arc flashes and outages increases with exposure of the electrical system to water and dirt. Additionally, the smell of burning, discoloration of wire, and changes in LED lights on switchgear are often urgent indicators of problems. The current routine for electricians in hospitals and universities is to physically walk through each building and check the switchgear equipment each morning. This can be a time-consuming and dangerous process.

Paper records

Electricians also walk through their facility to check for the position of older selector switches, which indicate power feeders in use. They record them onto a paper spreadsheet. Newer selector switches are able to send data about their status through the network to be accessed remotely.

"We call it the 'sniff' test, to look for the smell of burning wires."

- Electrical Supervisor

Story from the Field

Andrew, an electrical supervisor at a university, receives a call that the power is down in one of the buildings. Ten minutes later, he finally gets to the room of the switchgear and finds out that a leak in the chiller's room next door has caused a flood resulting in a short circuit. Had he been able to see the water coming in earlier, he could have turned the power off and prevented all the fuses of the gear from melting. This incident ended up causing the university tens of thousands of dollars.

“The whole campus would be black if all the alarms were real.”

- Electrical Supervisor



Electricians need more actionable information from their switchgear.

Though customers receive a multitude of signals from their switchgear, they are often still **unsure on how to prevent and troubleshoot** critical problems.

Resetting breakers

When troubleshooting a power outage, the first thing electricians usually do is reset the circuit breaker for the nearest switchgear. If that is unsuccessful in returning power, they will often check the next gear upstream and so on. It can be challenging to determine the true cause of the problem since they obviously cannot see how the power is actually flowing.

Nuisance alarms

During the installation process, Eaton PSA engineers will work with the customer to set equipment alarm settings. However, it's often difficult for the customer and the engineer to know which alarms will be truly useful in the future. Sometimes, customers will not even provide specifications, so PSA engineers will just set the defaults. Later on, the customer comes back and complains. Too many alarms are frustrating, and actual important ones have been missed.

"Excessive alarms become a nuisance after a point in time!"

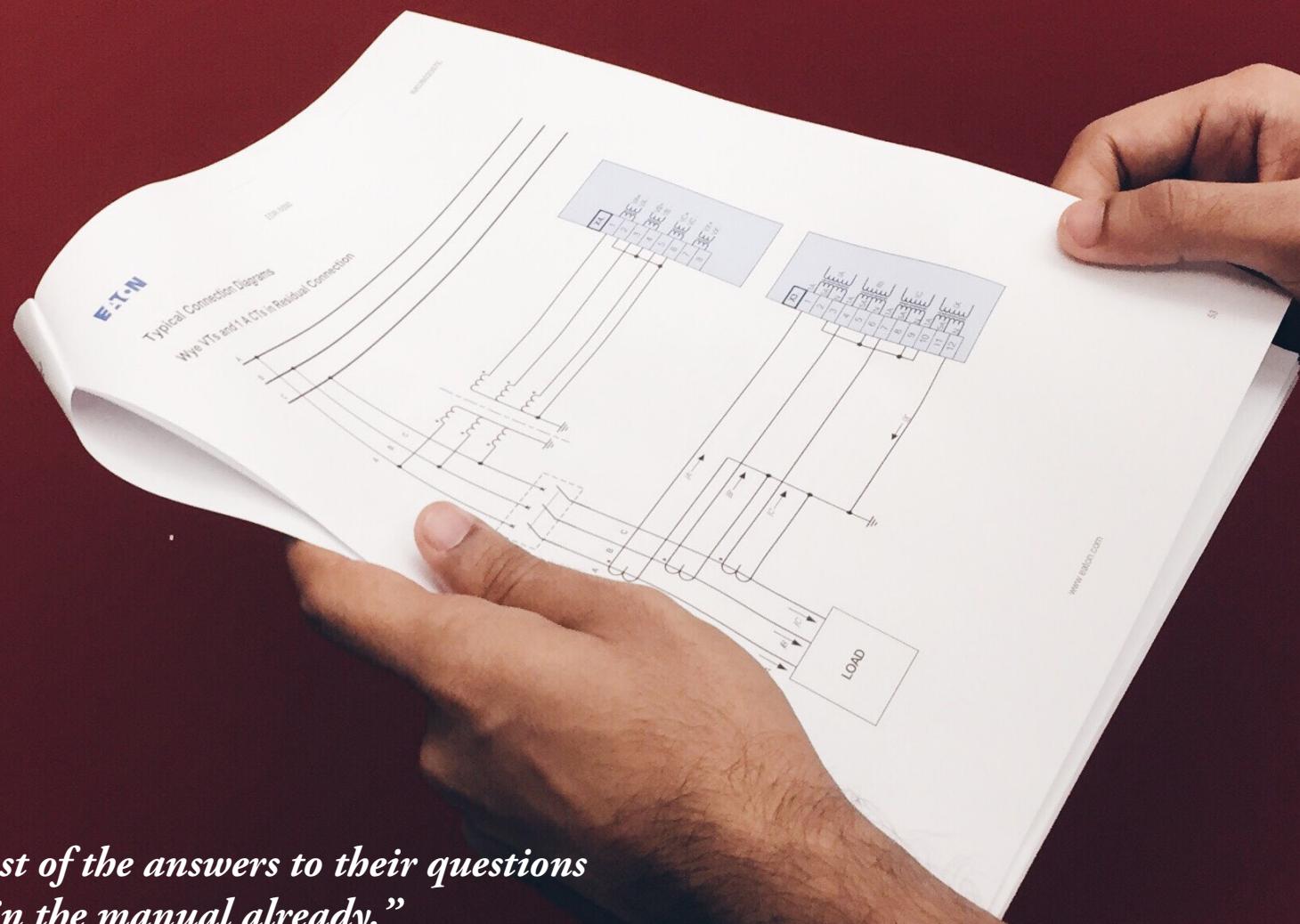
- Electrical Engineer

Story from the Field

Early morning, Steve, an electrical manager at a university, sees 54 alerts on his phone regarding the low-voltage switchgear lineup. He had never taken time to change the default alarm settings and by habit, he simply dismisses them all. However, on this occasion there has been an actual power outage! As construction had been going on, someone had jackhammered through an electrical cable, affecting power in 2 buildings. He receives a call after some time asking him when the power would be back. He then realizes that he had missed an actual alarm among all the other nuisance alarms.

*“Most of the answers to their questions
are in the manual already.”*

- Customer Integrity Team Member



Manuals are too exhausting to be useful, so electricians prefer to call Eaton directly.

Electricians want quick solutions, but they feel overwhelmed by the **complexity and length of manuals**.

Overwhelming manuals

Though many answers to simple and recurring problems can be found in manuals, they are inconvenient, extremely long, and easily misplaced. Eaton's website contains a frequently-asked questions pop-up powered by Nanorep, a customer support platform. However, the range of answers is currently limited. Usually, customers and engineers on-site find it easier to just call the Eaton Customer Integrity Team unless it is after hours.

Limited resources

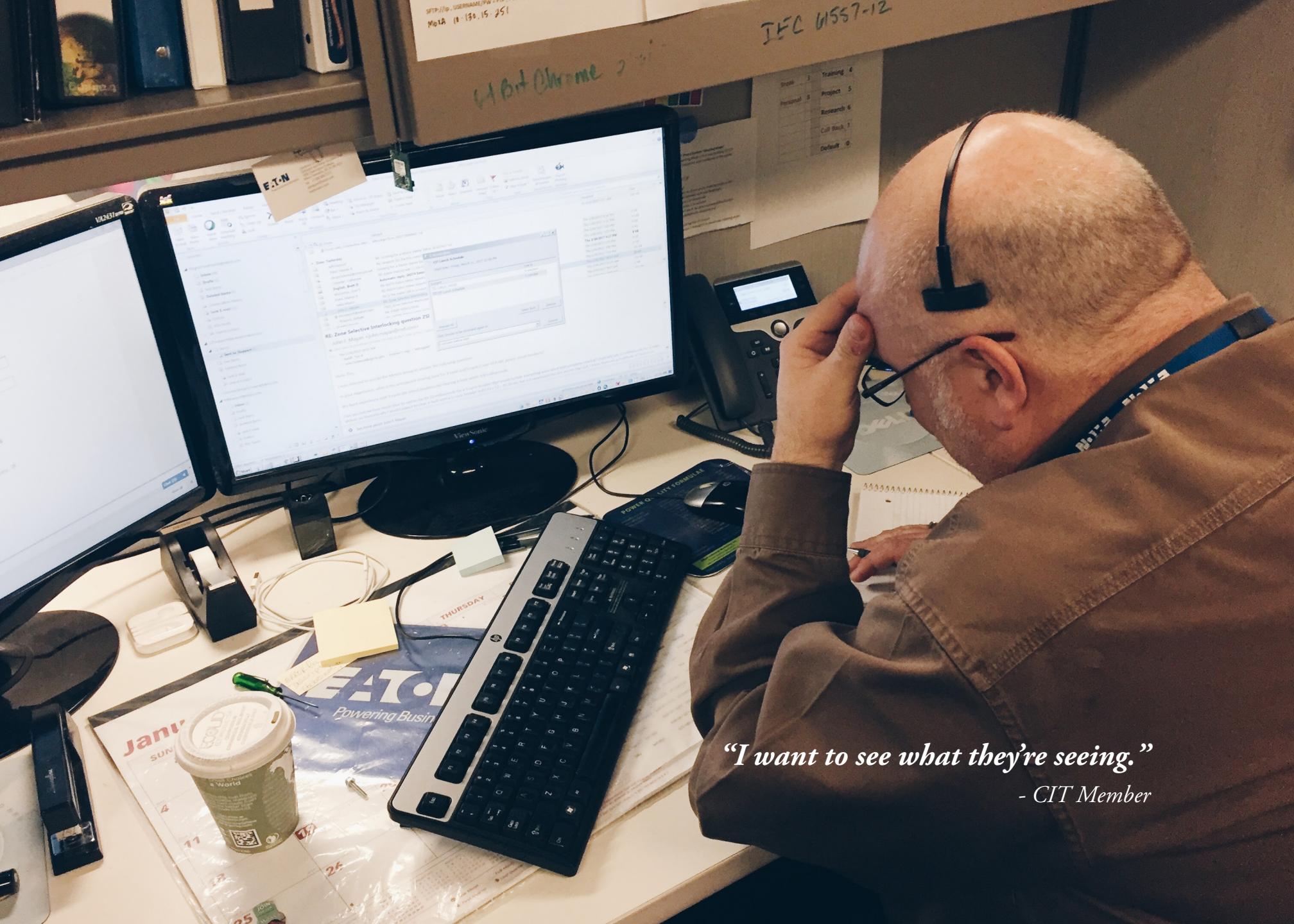
Four Customer Integrity Team members provide phone and e-mail support for hundreds of thousands of Eaton switchgear worldwide. Because of the immense amount of knowledge they need to have and be able to access, CIT members will have books and devices piled up around their offices. This responsibility can be overwhelming especially for new CIT members.

"We don't need to keep the drawings, you guys need that. Why do we need that."

- Customers

Story from the Field

Randy, a Customer Integrity Team manager at Eaton, receives a call about a meter failing to connect. While he initially thought it was a wiring issue, he later realizes that there had been a miscommunication. The customer actually only wanted to know how to change from one view of the user interface to another. The value he wanted to see didn't show up on the view he was on, leading him to think that the meter was not "connecting." Randy feels frustrated that the customer did not take the time and effort to go through the manual, which clearly contained the solution to his problem.



"I want to see what they're seeing."

- CIT Member

Remote support is limited by the lack of spatial and visual information.

Customer Integrity Team members provide support to on-site customers and service engineers via phone and e-mail, but often these modes are **inadequate to convey context**.

Need for visual information

CIT members need to understand the switchgear environment in order to provide relevant support, but every site and installation is different. The different versions of devices, their placement on the gear, the way they are wired, and the connection to third party devices are all variables which make every call different from the other. Part of the job of CIT members consists of trying to recreate the environment in their mind. As a result, they will often ask customers for pictures of the gear, or use Google Earth to picture the type of the site the customer is calling from.

Breakdowns in remote communication

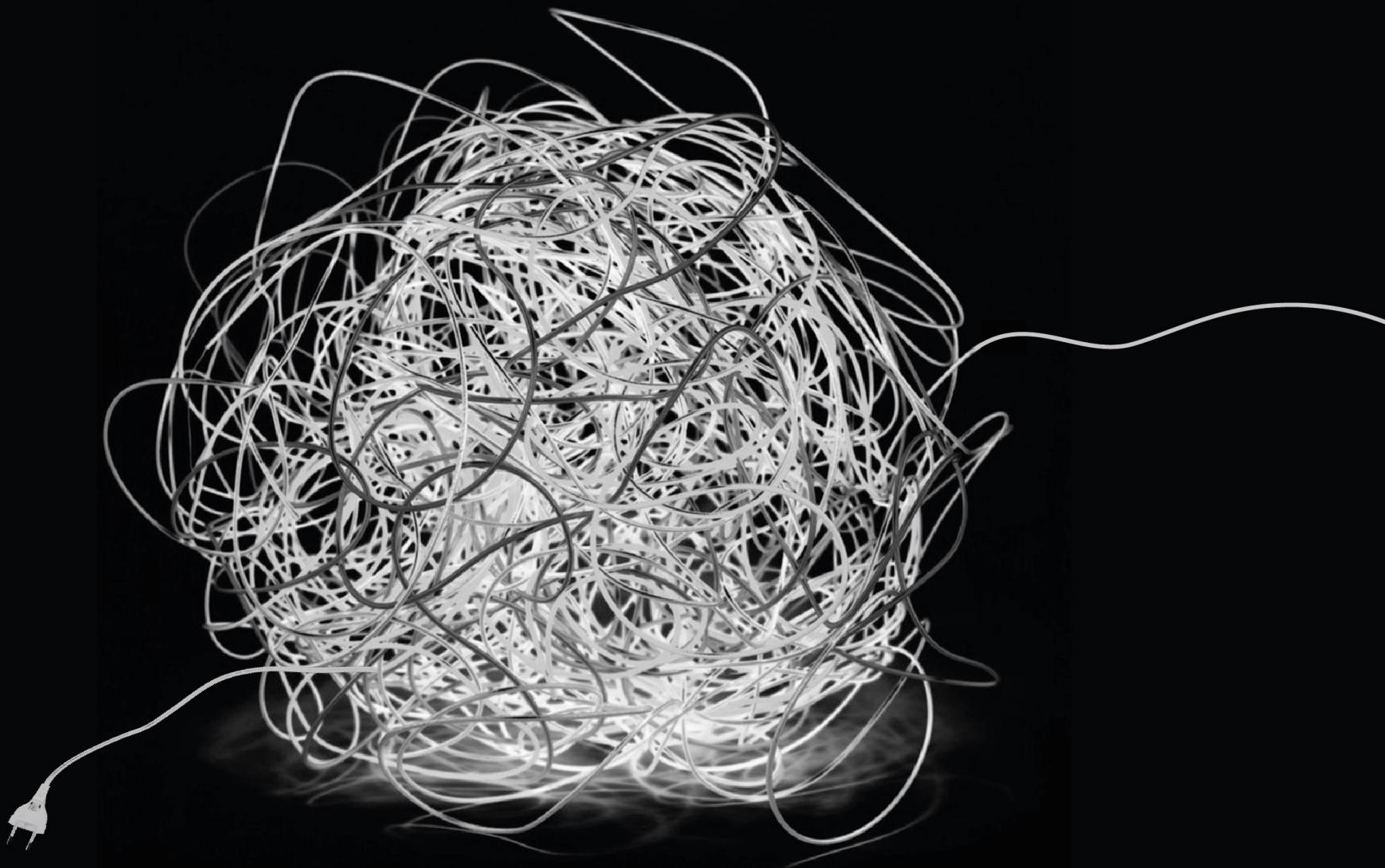
However, sending pictures breaks the communication flow since there can be time delays in uploading and downloading the photos. Additionally, language barriers, noisy environments, and unpredictability in the caller's background and knowledge can further degrade the communication.

"It sometimes takes up to 15 minutes to make the customer press the correct button."

- CIT Member

Story from the Field

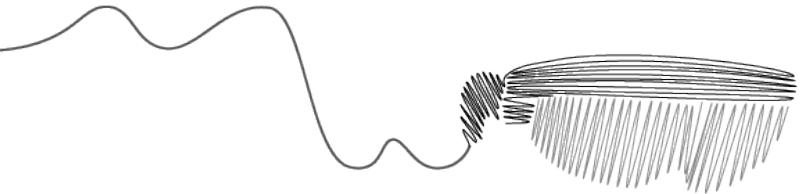
Randy, a Customer Integrity Team manager at Eaton, receives a call from Shane, a new field service engineer, about trouble with wiring a meter at a customer's site. As Shane is new to the job, he is not familiar with this particular type of gear. Randy first asks him what he sees in front of him. As Shane has trouble describing it, Randy asks him to send a picture. Shane disconnects the call and sends a picture. After Randy receives it, he realizes that the arrangement of the wires is different from what he imagined. He then annotates the picture and sends it back to Shane, before calling him back and explaining how to go about solving the issue.





Untangling Intricacies

Visions for the future



Expert Remote Assistance in AR

Help experts assist new engineers and customers remotely.

Our vision

Remote experts (e.g. members of the Customer Integrity Team, experienced engineers) need spatial and visual information to better understand the context they are dealing with. In order to help them assist newly appointed engineers, we envision an Augmented Reality app that would allow communication to happen more seamlessly.

Seeing and annotating the switchgear

In this vision, new engineers going to the field would be provided with their personal Augmented Reality headset. If they need assistance, the headset would connect them with a remote expert, who would receive a visual feed of what is happening thanks to the camera embedded in the headset. The expert would literally see what the engineer on-site is seeing. While providing guidance verbally (transmitted through the speakers of the headset), the expert could annotate objects that appear on their screen. The annotations would then appear within the field of view of the on-site engineer as an augmented layer of information.

Assisting new engineers, but also customers

While still in a learning phase, newly appointed Field Engineers need to resolve problems quickly on-site even though they might not be completely familiar with the equipment and devices in front of them. This system would make assisting more efficient. It could also be used to assist customers, who would use an augmented reality app downloaded on their phone rather than a more costly headset.



Robotic Monitoring Camera

Enable Electrical Supervisors to check on the switchgear without having to physically walk to the room.

Our vision

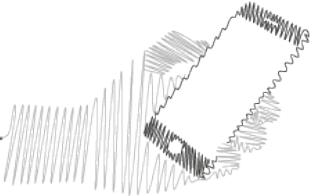
Electricians regularly walk around switchgear rooms to check for obvious issues. In order to make this tedious process more efficient, we consider a low tech solution for everyday monitoring of power management installations.

Keeping an eye on switchgear

In this vision, a camera would be mounted on a rail placed on top of the gear. From their office, facility managers or supervisors would be able to have a visual of the room and zoom in and out to see different parts of the gear. Instead of physically walking up to the gear, they could remotely check for issues in and around it. Once they get notified about a problem, they could quickly know if it involved an explosion, water, or smoke. The position of breakers and the UI of panels can also be checked.

Monitoring, but also troubleshooting

This monitoring camera could also benefit field engineers in their everyday work. Before going on-site, they could have a look at the gear, acknowledge what types of devices are on it, get the required manuals in advance and troubleshoot obvious issues such as a breaker not being fully racked in.



Chat-based Instant Support

Recognize gear equipment through pictures and provide information instantly through a chatbot.

Our vision

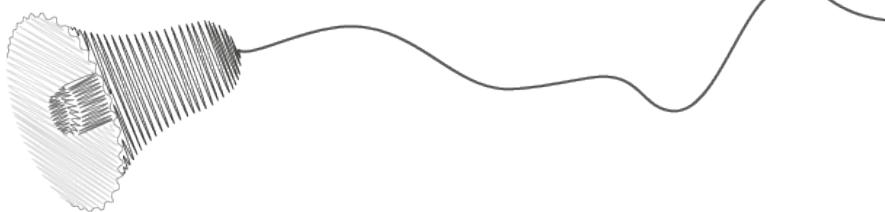
Manuals often contain the solution of problems related to switchgear. However, customers feel overwhelmed by them and end up not reading them. To address this issue, we envision a system providing a quick and easy way to extract relevant information about a piece of equipment or a procedure.

Filtering information for the customer

In this vision, an electrician or engineer would start by taking a picture of a part of the gear with their phone. Using machine learning-based image recognition, the app would recognize the photographed equipment. However, instead of having to navigate through a sea of information, the user is prompted to enter more specific questions to a chatbot. The bot would then engage in a conversation with the user and extract the relevant information from the documentation for them.

Empowering customers, but also engineers

While customers would get an immediate answer to common or small problems about their equipment, engineers could also benefit from this system. They would no longer have to look for documentation of old or unfamiliar equipment.



Conversational Switchgear

Control access to the gear and verbally warn electricians if safety requirements are not met.

Our vision

When working with switchgear, hazard labels are not strong enough, and fighting complacency about safety is an everyday battle. To help make sure people follow safety procedures, we envision a switchgear which would verbally remind them about the requirements.

Dealing with safety in a proactive way

Let us imagine someone entering the switchgear room. A camera embedded within the gear could detect if this person is wearing the correct protective equipment. If not, a conversational agent would remind them about the arc flash requirements. Providing warnings verbally and in context would prove to be more efficient than regular labels. A smart locking system could also be utilized to ensure that people can work on the equipment only if they are wearing the appropriate PPE.

Reminding verbally, but also visually

Rather than using the default conservative values indicated on stickers, the arc flash zone could be calculated dynamically by the switchgear. The arc flash boundary could then be projected in front of the switchgear which could provide better visual feedback than the stickers currently attached to gear, which ironically require the person to move into the arc flash zones to read.

About Us



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Acknowledgements

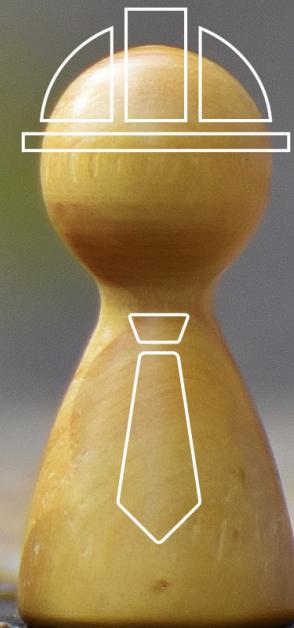
Thank you for your support, guidance and hours of fun meetings!

Eaton Corporation

Rufus Barnes
Michael Hanne
Deborah Mort
Todd Shaak
John Stampfel
Robert Yanniello

Faculty Advisors

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Carnegie
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Team
Spark

EATON

Spring 2017