

# How extended reality empowers the electrical operation and maintenance workforce

A breakthrough for safety, efficiency, and resilience

by

Markus Hirschbold

Claude Houbart-Santini

Mario Ibrahim

Jerome Talbot

## Executive summary

While electrical distribution systems have become more complex, seasoned electrical professionals are retiring, and operational budgets are tightening. This leaves facility management teams with fewer, less-experienced people to maintain critical assets and respond to any threats to electrical continuity while frequently working on unfamiliar equipment under stressful conditions. Using extended reality (XR) technology – including virtual, augmented, and mixed reality – is already well-established in applications like healthcare, manufacturing, and industrial training. This paper demonstrates how emerging XR tools apply to electrical distribution to accelerate training while empowering the facility workforce to improve safety and efficiency, and save time isolating risks and restoring power.

## Introduction

It has never been more important to keep facilities running safely and reliably. Interruptions to business-as-usual processes can be financially and operationally devastating for:

- Data centers and trading floors where every second of downtime can mean a massive loss of revenue, angry customers, and reputation damage.
- Continuous manufacturing or processing can incur the high costs of retooling and restarting.
- Healthcare when a power loss can interrupt essential services and even put human lives at risk.

For every type of facility, a well-maintained and reliable electrical infrastructure is fundamental to maintaining operational continuity and helping ensure safety for people, equipment, and structures. When interruptions occur, facility teams often face a conflict between restoring power as quickly as possible and doing so safely.

### Keeping the power on in the face of greater complexity

Electrical distribution technology has advanced greatly over many decades, and the landscape continues to change. Newer equipment is now more reliable by design but is also more complex.

For example, in the past were single function, standalone mechanical relays. Today, the 'smart' electronic relays inside circuit breakers combine multiple digitized protection functions with the possibility to coordinate the operation of multiple devices (**see Figure 1**).



**Figure 1**

*Comparing relay and circuit breaker technology of the past to today's newest models.*

These advanced functions help optimize safety and power continuity but require a longer learning curve to fully grasp all capabilities and maintenance requirements.

Multiply this by many separate devices, typically available in various sizes and models, from numerous manufacturers, with differences in appearance and capability. Consider also that troubleshooting or replacing a single piece of equipment can involve many procedures and steps.

Beyond the device level, electrical distribution systems have become much larger in scope and complexity in relation to the size expansions of facilities and campuses. Several more types of electrical loads are being supplied, such as electric vehicle chargers, and many loads now have embedded digital controls that can make them more sensitive to the quality of power.

To enhance sustainability and resilience, many facilities are also adding on-site renewable energy generation, energy storage, or a complete microgrid. These resources and controls need to be carefully managed to maximize their value.

As a whole, the complexity of electrical equipment and systems makes it more challenging to train facility engineers and technicians and properly maintain equipment. During operations, it may also be difficult to know where to go and what the safest procedure is when responding to risks or restoring power.

## Figure 2

*The traditional way of studying electrical distribution systems and equipment operation is very manual, requiring the review of single-line diagrams, operation manuals, or other documents.*



## Facility teams have to do more with less

Organizations also face challenges with their facility operations and maintenance workforce as experienced personnel reach retirement age. An estimated ten thousand Baby Boomers turn 65 every day in the U.S., and this trend will continue until 2030.<sup>1</sup> A report on Europe's aging workforce notes that "for every 10 Gen Z, there are 12 seniors aged 65+ in the EU," and over 15% of technicians and associate professionals are aged 55+.<sup>2</sup>

As electrical professionals retire, there are two possible outcomes:

1. With tighter budgets, vacant positions might not be refilled, reducing headcounts and putting more pressure on the remaining team.
2. Vacated positions may be filled by younger, inexperienced new hires that start with no working knowledge of the unique aspects of a facility's existing electrical system.

It can be a steep learning curve for new trainees as they must work safely, sometimes on unfamiliar equipment, and often under stressful conditions. They must master operational, maintenance, and safety practices – many of which are specified in long and detailed technical manuals and procedures.

Further, facility teams now have a greater range of responsibilities. A single team (or person) can be responsible for more than one facility and aspects of facility performance. For example, the pandemic made indoor air quality and other factors of occupant well-being a higher priority for facility teams.

These pressures result in electrical operations and maintenance procedures taking longer to complete and becoming more prone to human error. Those errors can cause equipment damage, safety issues (like electrical fires), and downtime. When there is a critical risk or event, it can take longer to respond to, to isolate, and to correct and restore power.

## Moving beyond identifying risks to guiding actions

Another advancement in recent decades has been integrating digital communication into meters, circuit breakers, relays, sensors, and other energy assets. It is now common for distributed devices to be networked, continuously uploading data to a facility- and cloud-based energy and power management system (EPMS) software. Many devices also offer local, hands-free access using a mobile device to view data or, in some cases, enable remote control functions.

The power analytic capabilities of EPMS help facility teams and service providers reveal energy inefficiencies, monitor equipment conditions, determine maintenance needs, identify risks, and isolate root causes.

However, during the final action step, technical personnel typically had the stressful challenge of quickly determining the required complex series of manual steps. Whether responding to an event or performing an essential maintenance task, technicians must know what buttons to press (and in what order) to ensure simultaneous power availability and safety.

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<sup>1</sup> "4 Ways for HR to Overcome Aging Workforce Issues," SHRM, 2017. <sup>2</sup> "Leveraging Europe's Aging Workforce," AESC.

This situation has hindered facility teams and contracted service provider's overall response time and efficiency. This reflects a growing need for digital solutions that can provide – in a convenient, unified way – real-time operational data, digital equipment manuals, and online procedures directly into the hands of equipment operators.

### **Extended reality (XR) technology can make this possible.**

The term XR encompasses the full scope of virtual reality (VR) and augmented reality (AR), as well as combining the two technologies as mixed reality (MR).

**Figure 3**

*A technician using augmented reality technology to reveal the real-time conditions inside a physical electrical cabinet.*



“The XR industry is expected to grow from \$33 billion in 2021 to a staggering \$125.2 billion by 2026, at a CAGR of 30.6%.”<sup>3</sup>

XR is well-established in several industries and has now come to electrical distribution management with the potential to:

- Greatly save time for personnel
- Reduce errors
- Save money by reducing downtime and improving equipment performance
- Accelerate technician training

This paper will present:

1. Recent trends and benefits of XR
2. The advances XR makes possible for electrical applications
3. Four common scenarios where XR tools are helping improve electrical procedures, response, and training
4. The future of XR for electrical applications

<sup>3</sup> “5 ways industrial companies can use extended reality to slash training costs and downtime,” CIO, June 2021.

## Finding purpose for extended reality

When we refer to 'extended reality,' it is important first to define the differences between the two technologies encompassed by that term: **virtual reality** (VR) and **augmented reality** (AR).

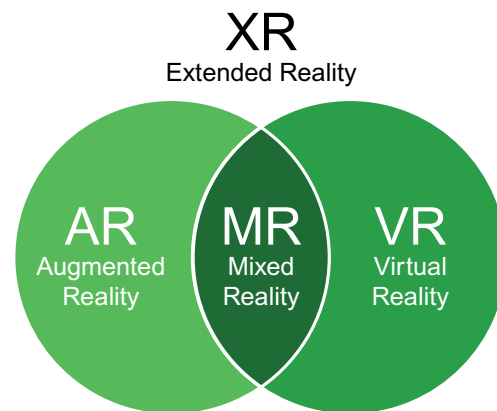
According to Intel, "VR is the most widely known of these technologies. It is fully immersive ... you'll experience a computer-generated world of imagery and sounds in which you can manipulate objects and move around using haptic controllers."<sup>4</sup> A prime example of VR is flight simulators used to train pilots.

In contrast, "AR overlays digital information on real-world elements. [It] keeps the real world central but enhances it with other digital details, layering [a] new strata of perception and supplementing your reality or environment." A good AR example is the emergence of 'smart windshields' in vehicles, in which GPS navigation data is overlaid on your view of streets ahead of you.

These two technologies can be combined into **mixed reality** (MR), where a person can interact and manipulate real physical items as well as virtual ones (**see Figure 4**).

**Figure 4**

*Extended reality (XR) is the complete scope of augmented reality (AR) and virtual reality (VR) technologies and their combined use as mixed reality (MR).*



Beyond vehicle GPS, other industry AR examples include:

- **Healthcare** – According to Forbes, "Augmented reality has proven to be beneficial for training surgeons and is a new approach in performing detailed surgical operations. Superimposing radiographic images on live images allows visualization of the surgical site in a way that was not possible before."<sup>5</sup> Universities are also using AR to "peel back virtual tissues on digital cadavers and display it to their students as to how it is done."<sup>6</sup>
- **Manufacturing** – AR is used to help workers on assembly lines for smartphones, automobiles, jet engines, etc., to view parts and help them assemble machines with greater precision and speed while avoiding errors.
- **Industrial training** – According to ISA, "Industries like oil and gas refining and power generation have already been turning to AR ... to transfer a high level of skill, plant knowledge, and situational awareness to each member of the team as efficiently as possible. [It] allows training and assessment ... in the safe and controlled environment of the classroom, providing the freedom to fail without risk."<sup>7</sup>

"A recent survey of manufacturers shows that 56% of those polled said they have implemented some form of AR/VR technology into their organization over the last 12 months. 29% said they are realizing more than a 25% increase in productivity efficiency [while] 61% said they are realizing as much as a 20% savings in costs."<sup>8</sup>

<sup>4</sup> "Demystifying the Virtual Reality Landscape," Intel. <sup>5</sup> "10 Intriguing Uses Of AR Technology In Industry," Forbes, July 2020. <sup>6</sup> "8 Industries Augmented Reality is radically Transforming," GoodFirms. <sup>7</sup> "How Virtual Reality Makes Industrial Training More Immersive and Meaningful," ISA Interchange. <sup>8</sup> "Manufacturers Are Turning to AR/VR to Reduce Production Costs," Design News, June 2020.

## The emergence of XR for electrical systems

Extended reality is now emerging in the electrical industry, specifically for operations and maintenance (O&M).

An **XR system** organizes relevant data – e.g., on equipment, procedures, electrical network status, etc. – and enables field data access via mobile tablets, smartphones, digital glasses, or XR headgear.

When using **AR**, the real device or object, such as an electrical cabinet, can be superimposed with a schematic diagram or step-by-step procedures. It can also be overlaid with live data, showing selected readings from each device or sensor in the cabinet.

In the case of **VR**, a virtual environment is created that represents, for example, a functional piece of equipment or a complete electrical room with all associated equipment. There are no ‘real’ objects with VR, but the virtually modeled objects can appear three-dimensional and very realistic. In the case of mixed reality, a VR modeled image can be presented to the technician while they are using AR to view information about the real equipment in front of them.

In this respect, **both AR and VR are essentially ‘digital twins’ of your actual functioning electrical equipment.** Many types of digital twins have emerged for building design, construction, and operation. This includes those created by building information modeling (BIM) systems and electrical system modeling and simulation.

For AR and VR used in electrical O&M, real-time data is accessible from the database of an energy and power management system. It integrates with a graphical digital twin of the electrical switchgear, sometimes including equipment from multiple vendors.

Further layers of information can also be accessed, such as electrical diagrams, images, or videos. With AR, you can use a capability akin to ‘X-ray vision’, virtually revealing the internal components of an actual cabinet, machine, or device.

To enhance safety in a real operating environment, varying levels of XR access can be granted, depending on user roles and responsibilities.

XR for electrical systems is somewhat analogous to a vehicle GPS with a smart windshield. Even if the driver knows their home city quite well, the GPS will help find the fastest, safest route to the destination while tracking the speed and alarm status of the vehicle.

Similarly, even for highly skilled engineers, XR can help:

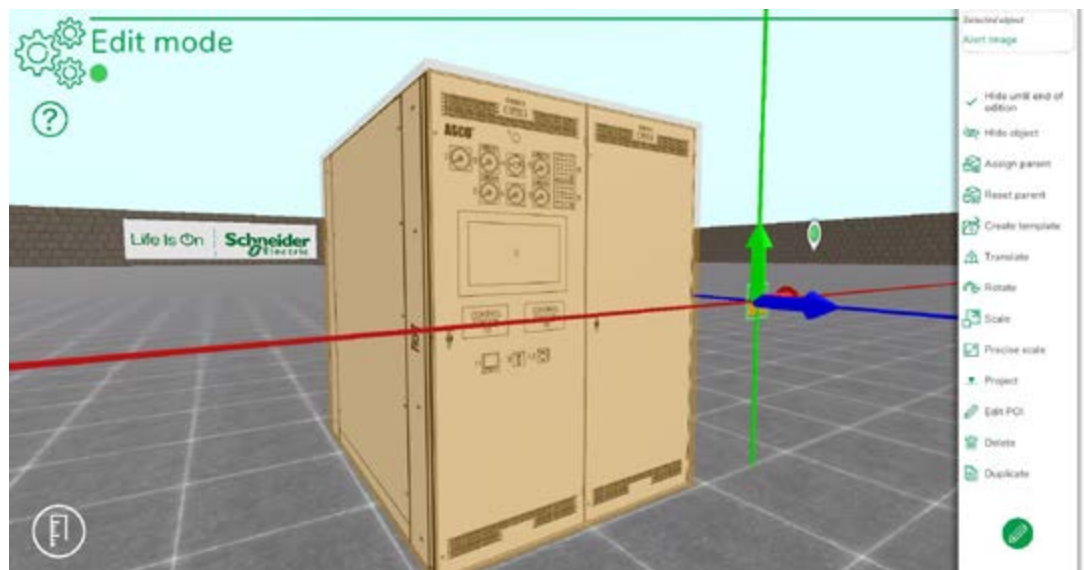
- Operate and maintain electrical equipment in a faster and safer way by reducing human errors
- Simplify procedures for complicated, potentially hazardous tasks performed infrequently
- Display the real-time performance and state of the electrical equipment

The following sections present a few practical scenarios to illustrate these benefits.

### How are electrical system XR solutions delivered?

Creating customized AR/VR solutions typically requires many hours of 3D developer labor – at a high cost. However, the newest XR solutions for electrical O&M offer a more affordable approach that uses a plug-and-play architecture comprising of default AR and VR components representing common electrical equipment.

When supported by vendor services, a ready-to-use XR application can be provided to a facility team, complete with all digital equipment models and functionality. Alternatively, provide the facility team with an authoring tool and training, enabling the organization to architect and build its own applications.



**Figure 5**  
*'Builder' view creation of an AR/VR model.*

## Scenario 1 – Regular operational check

XR can help to enhance electrical distribution monitoring and alarming. When doing regular rounds, a technician walking by electrical switchgear will be able to use their smart device or digital glasses to visualize the condition and state of assets virtually overlaid on top of equipment (**see Figure 6**).

Information can include real-time power and energy measurements, temperatures, alarm conditions, or other parameters. Having relevant live data displayed on top of associated devices can save time verifying that equipment is running within acceptable tolerances.

If enabled, the technician can also remotely access device settings and, if needed, access virtual single-line diagrams to correlate against readings on equipment to confirm specific operation outcomes.



**Figure 6**

A tablet used to view an augmented reality display showing real-time thermal measurements superimposed on top of each device in an electrical cabinet. The technician is also alerted to an alarm condition, as indicated by the virtual message in the upper right corner.



## Scenario 2 – O&M procedures

“Mixed reality increased training efficiency by 60% [and] task efficiency by 60%... shows a three-year ROI of 177%... and a payback period of 13 months.”<sup>9</sup>

As noted previously, XR is ideal for supporting operational or maintenance procedures that are not done often but may also be complicated, including:

- Locating the right equipment.** Using spatial awareness, augmented reality can help identify which cabinet and device should be serviced. By pointing the mobile device or digital at the equipment, the system will accurately recognize the type, model, and specific piece of equipment requiring attention. It can also create an apparent link between the elements in an electrical one-line with the real equipment by aligning a virtual diagram over the switchboard. This reduces the potential for human error due to equipment misidentification. **(See Figure 7).**

**Figure 7**

The XR system helps the technician ensure they are addressing the right equipment.

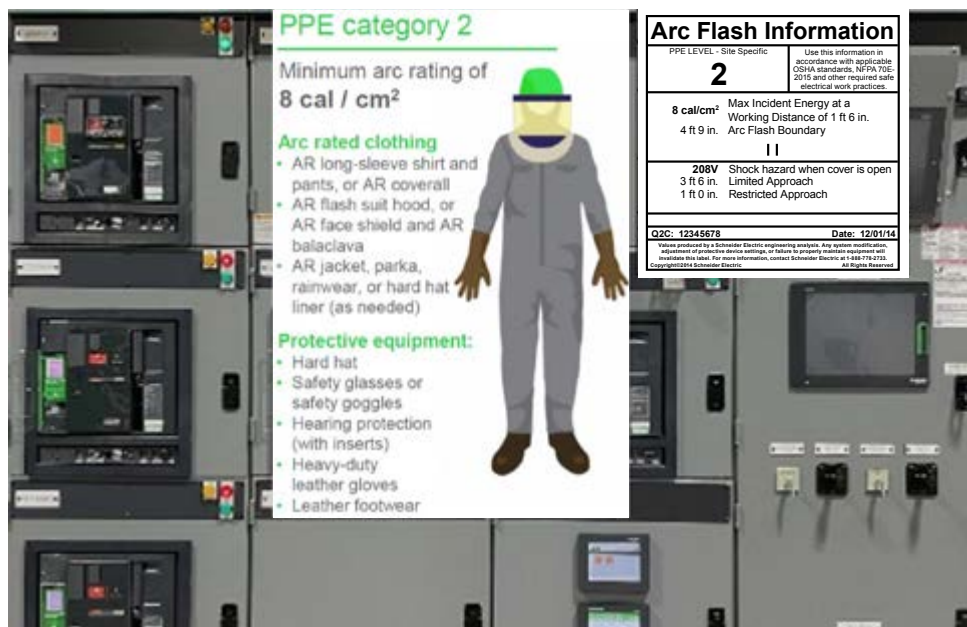


<sup>9</sup>“The Total Economic Impact™ Of Mixed Reality Using Microsoft HoloLens 2,” Forrester, November 2021.

- **Enhancing safety.** 3D geo-positioning can be used for safety zone awareness, visually highlighting risk zones (such as arc flash boundaries), and warning the technician in case of area crossing. It can also pop up instructions for required personal protective equipment (PPE). **(See Figure 8).**

**Figure 8**

*Example of an XR system detecting and warning a worker that they have crossed the arc flash boundary, informing them of PPE required to operate or service the equipment.*



- **Gaining 'X-Ray vision.'** A technician can virtually "open" a cabinet door and "see" inside the equipment to reveal internal components without risk. **(See Figure 9).**

**Figure 9**

*XR enables a technician to see behind the door of an electrical cabinet with 'X-ray vision' for increased safety.*



- **Following step-by-step procedures.** The XR system can present an exact step-by-step procedure to follow. **(See Figure 10)**. Exit conditions can ensure that a prerequisite is completed before the next step is started. For complex procedures, 3D model overlays with instructions can be used to assist the technician.

**Figure 10**

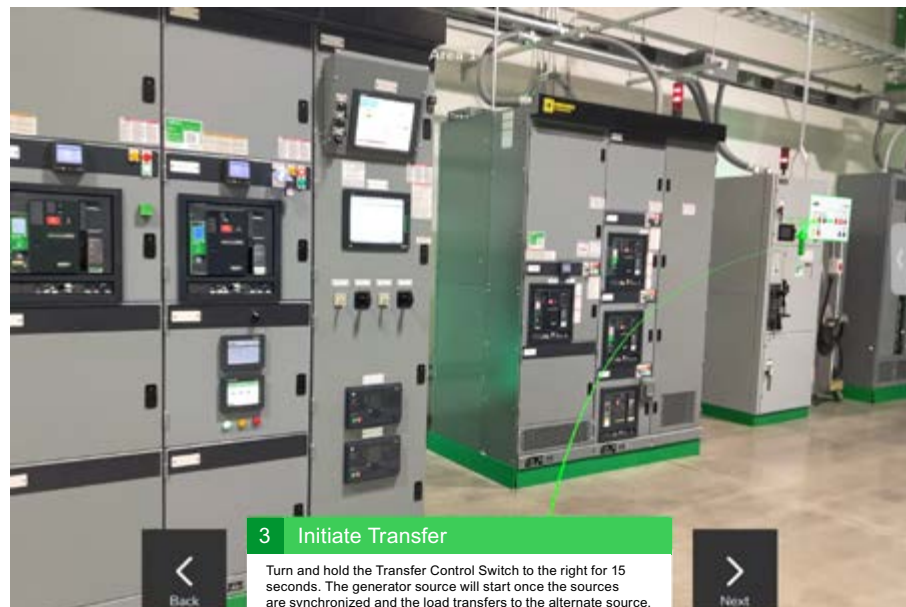
The XR system will present a step-by-step procedure first, indicating which device to service (see green arrow) and what first step to take. Once accomplished and validated by the XR system, the procedure then points to the next action to take.



- **Wayfinding to other equipment.** XR can help a technician navigate to multiple pieces of equipment for more extensive procedures. **(See Figure 11)**.

**Figure 11**

Wayfinding directs the technician to other equipment if an action is needed there.



- **Remotely operating equipment.** If enabled, the XR system can allow a smart device to be used for the 'nearby operation' of equipment without being in harm's way.  
*NOTE: This capability should be optional and disabled if considered a security risk.*
- **Accessing supporting documentation.** The technician can quickly and easily access the most up-to-date "as-built" drawings, documentation, and multimedia for the device or system. **(See Figure 12).**

**Figure 12**

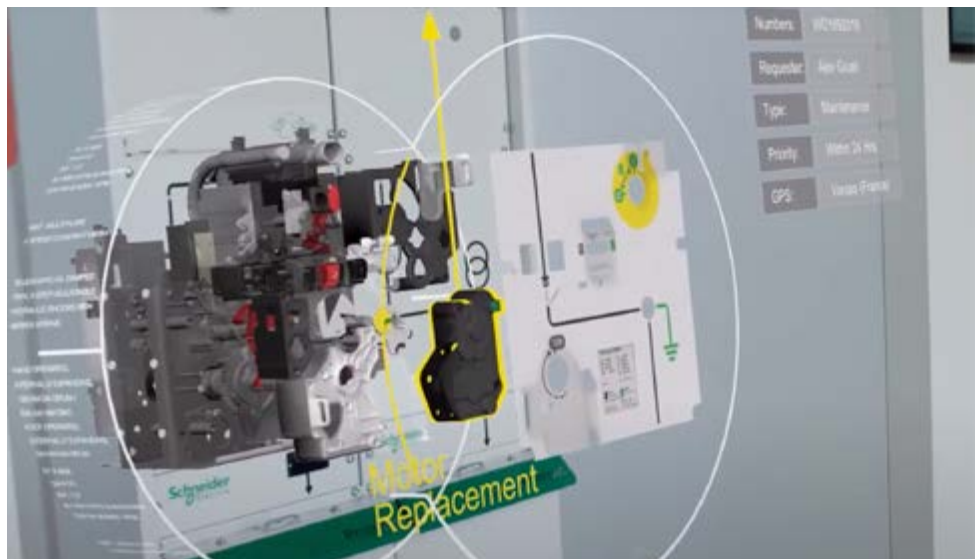
The XR system can quickly find and reveal other required documentation or information, such as a virtual schematic that can be correlated with the switchgear operation.



- **Enabling remote assistance.** If needed, the XR system can help the technician or engineer quickly connect to remote assistance from an off-site expert. **(See Figure 13).**

**Figure 13**

For complex procedures, the XR system can present a virtual representation of the equipment in a MR scenario. In this example, the AR system presents a 3D VR model overlay of the breaker, identifying the part requiring service (e.g., motor replacement).



Using these tools can result in faster and more accurate repair, reduced potential for error, and enhanced safety. When multiplied by many such procedures each year, the potential cost efficiencies and safety improvements can be significant.

## Scenario 3 – Critical event response

“Various studies show that companies found a 50% reduction in downtime, 30-50% reduction in time taken to resolve an issue, 30% reduction in operational expenditure, and these companies are able to operate with 25% less manpower after adopting AR into their operations.”<sup>10</sup>

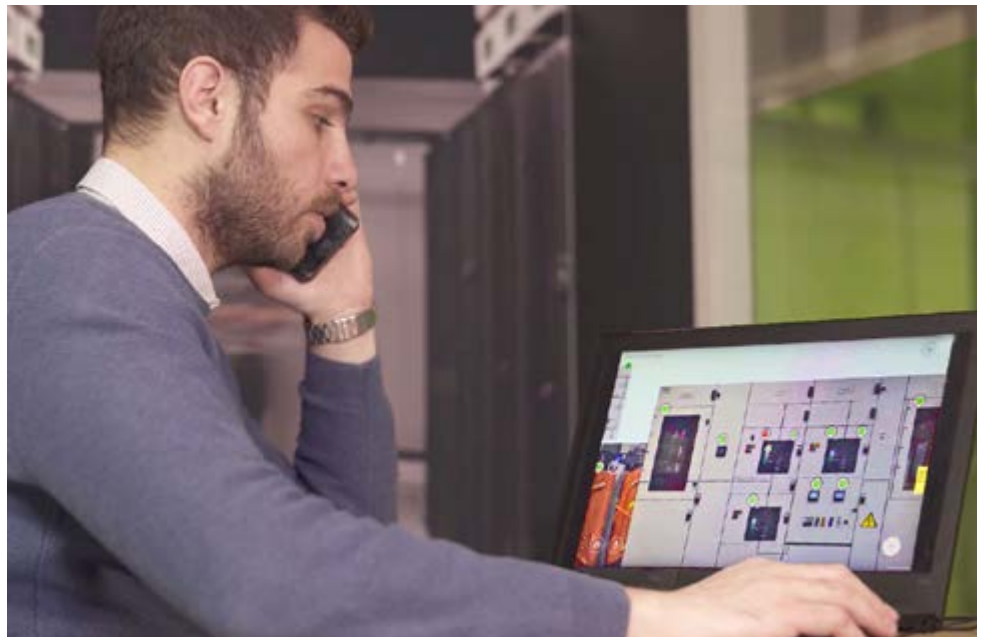
Whether it is a risk to uptime or an outage, the event will typically first be identified by a facility engineer or contracted service company. If they use an energy and power management system (EPMS), they will receive an alarm on their desktop or mobile device. That alarm message may also be shared with other personnel. The alarm can also be passed to the XR system, so technicians working on equipment can be alerted in real-time.

The engineer will then use the EPMS application to identify the root cause and isolate the location of the problem. **(See Figure 14)**. The next step is to coordinate with the maintenance team to go to that location and address the issue. This is when XR offers advantages in response time and effectiveness.

- **Preparing the technician ahead of time.** The engineer can communicate through the XR system, sharing a view of the location to help prepare the technician before they arrive on site. Before going to the field, operators can view the action on the AR system. This enables them to identify all needed tools and be more efficient since they have already virtually performed the task.
- **Wayfinding to the location.** The XR system will then help guide the technician to the right location in the facility and the right equipment.
- **Collaborating inside the XR world.** The engineer can send additional information (e.g., images, notes) to the technician through the XR app. The engineer can become part of the technician's XR experience, seeing the same XR view as the technician and “being on-site” by becoming a ‘virtual assistant’ avatar inside the technician's XR environment.
- **Guiding the technician to the problem.** The engineer can now use a virtual laser pointer to guide the technician to the exact device needing attention. **(See Figure 14)**.

**Figure 14**

*From the laptop in their office, an engineer will typically first use the analytic tools in the EPMS to identify the root cause of a problem, then the XR system helps the technician determine its physical location.*



<sup>10</sup> “Augmented Reality in Maintenance and Repair”, VSight, January 2020.

- **Generating reports.** The technician can save time by starting to create a maintenance report during the procedure.
- **Enabling continuous improvement.** During a procedure, if the technician identifies an error in the instructions or wishes to recommend simplifying a step, they can add notes through the interactive XR interface. These notes will then be shared with the developers and future users. In this way, the XR system is a living resource that can continuously improve and evolve.

In these ways, XR technology helps reduce costs by saving personnel time, reducing human error, and restoring power faster. Digital guidance in the field also avoids the time needed to obtain more information.

Additionally, similar to O&M procedures, using XR for critical event response can be supported by remote expert assistance if required.

**Figure 15**

*When collaborating with the technician, the engineer becomes an avatar inside the XR experience. Using a virtual laser pointer (red), the engineer can point the technician to the equipment they need to address.*

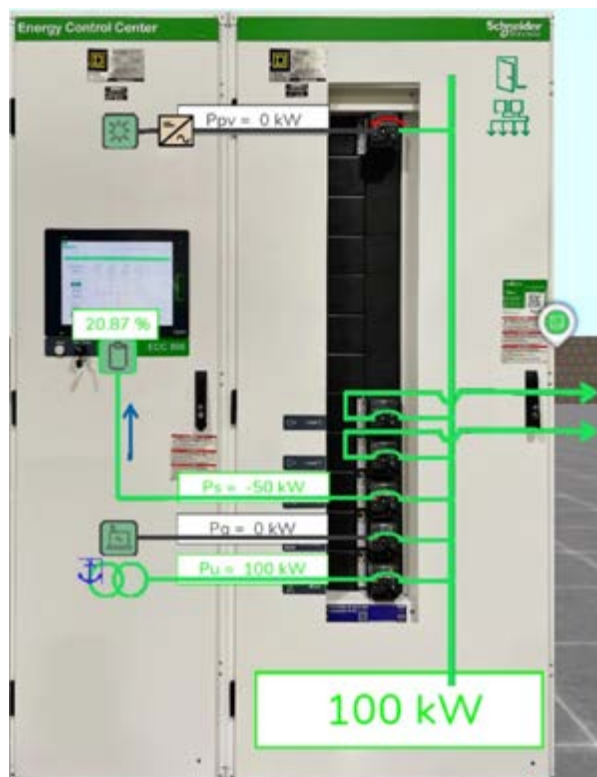


## Scenario 4 – Training

Similar to a flight simulator, accelerate electrical distribution system training with VR. With fewer experienced mentors due to retirement, VR-based training offers an effective alternative.

PCs or tablets can display a digital twin that simulates the actual equipment, including simulated real-time operational data. The AR environment developed for O&M purposes can be mapped directly to the VR environment, making training an accurate representation of real-world conditions.

Highly realistic training sessions guide trainees with maintenance procedures or problem response steps. As with O&M procedures, the equipment can be superimposed with live data or other helpful information like a functional one line. **(See Figure 16).**



**Figure 16**

A VR training simulation shows a virtual model of actual electrical equipment with superimposed, real-time measurements and a virtual schematic overlay.

This is a revolutionary way to deliver training that is fully tailored, interactive, and conducted with increased safety without physically having to be on-site. It further means that procedures can be practiced with little to no risk of injury or causing outages.

Demonstrations have confirmed that personnel learn quickly in these kinds of simulations. The effectiveness increases as the training context and case are closer to reality. Repetition also reinforces training, and with VR-based methods, trainees no longer have to wait for coordinated in-class events, they can run all training simulations from anywhere at any time.

## The future of XR for electrical systems

XR technology for O&M applications will continue to evolve, extending value across the entire building lifecycle. Here are a few advancements that may be possible in the future:

- **Seamless integration of digital twins.** Building information modeling systems will continue to integrate more tightly with other design and operating systems. For example, the electrical digital twin created by BIM will more seamlessly map over to the digital twin used in the final facility operational systems. In this way, the electrical design model will become the basis for the EPMS used for power management and for the XR models. This makes it faster to create a complete XR environment.
- **Procedural traceability.** Record steps taken by technicians within the XR environment to enable playback of entire procedures at a later time, if necessary.
- **AR interaction with the facility work order system.** Suppose the technician determines that part(s) replacement is required during a maintenance or repair procedure. In this scenario, they will photograph the equipment and submit a work order through the XR system to the facility's service desk. The system will determine whether the required part(s) are available, and if not, the part(s) can automatically enter the supply chain for ordering. This end-to-end task of repair assessment, parts ordering, and replacement scheduling may only take several minutes. By contrast, traditional maintenance methods could require hours or even multiple days.
- **Libraries of pre-scripted procedures.** Consider how YouTube contains instructional 'how to' videos for almost any consumer product. Now imagine a similar repository for XR-based O&M-guided procedures for all common electrical equipment.

## Conclusion

Just as the newest AR-enhanced GPS tools are helping drivers navigate with greater efficiency and better manage the performance of their vehicles, electrical system extended reality is enabling a wide range of powerful benefits for facility management teams:

1. **Enhanced safety** – XR alerts technicians when nearing or crossing safe boundaries, describes PPE requirements, and visually delivers clear guidance and procedures to help reduce human error and unsafe practices.
2. **Improved cost efficiency** – XR prepares technicians before they arrive on-site, saves time in performing procedures, and enables faster access to information that helps avoid the need for return trips.
3. **Enhanced resilience and reliability** – XR helps engineers and technicians closely collaborate and work with greater confidence to address risks and restore service faster.
4. **Training efficiency** – The combined AR and VR experience helps improve skills transfer by providing trainees context and cases closer to reality, with the ability to repeat exercises anywhere, at any time.

Whether a technician is highly experienced or a new trainee, XR offers a new layer of tools that can help make work safer, more efficient, and more effective.

From live data superimposed on equipment to 'X-ray' vision inside cabinets, wayfinding help to 3D-animated procedures, and virtual collaboration all the way to multi-dimensional information access, XR is enabling an exciting workflow breakthrough for facility teams and service providers.



## About the authors

### **Markus Hirschbold (P.Eng., CEM, PMP)**

Markus is responsible for the offer creation of EcoStruxure Power, the IoT-connected solutions of Schneider Electric, designed to improve every aspect of power distribution systems. He has held various key positions in R&D, Services, Power Quality, Project Management, and Offer Marketing in over two decades of tenure at Schneider Electric.

### **Claude Houbart-Santini**

Claude is responsible for the Electrical Distribution Workforce Empowerment program, a dedicated services program targeted at Schneider Electric's channel partners and end-user operators. She has held various positions in Customer Training and has developed and deployed digital training programs for many global companies.

### **Mario Ibrahim**

Mario is the Director of Strategy & Innovation at Schneider Electric. He has built a proven track record of performance throughout his 20+ year career in critical power automation and management with global technology leaders. A lifelong New Jersey resident, Mario has served as an engineering professor and holds a Masters's degree in Electrical Engineering from Princeton University, an MBA from Rutgers, and a Bachelor's degree in Computer Engineering from NJIT.

### **Jerome Talbot**

Passionate about technologies and innovation, Jerome Talbot is the Offer Launch Leader of the Electrical Distribution Workforce Empowerment offer. Throughout his 20+ years of industrial experience, Jerome Talbot has held different Sales & Marketing roles in the Industrial Automation industry, including Business Model Transformation, Key Account Development, and strategic Business Development.

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EcoStruxure XR Operator Advisor, a comprehensive application from Schneider Electric is tailored for your electrical distribution needs to accelerate training while empowering the facility workforce to improve safety and efficiency, and help reduce risks for operation and maintenance tasks.

The topics mentioned in this whitepaper are comprehensive and forward looking, and are not all necessarily yet included in this offer.