World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(Research Article)

Check for updates

Supervisory control and data acquisition for localized grids in extended reality

Joseph M. Dowell *, Penrose Cofie, Anthony Hill, John Fuller, Justin Foreman and Kazeem Olanrewaju

Department of Electrical and Computer Engineering, Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, Texas 77446, United States of America.

World Journal of Advanced Engineering Technology and Sciences, 2025, 15(03), 1661-1672

Publication history: Received on 26 April 2025; revised on 11 June 2025; accepted on 13 June 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.15.3.1080

Abstract

Supervisory Control and Data Acquisition (SCADA) systems are essential to the operation of intelligent off-grid power systems. In this study, extended reality (XR) technology is used, to perform control room duties remotely, in a combination of real and digital environments, thus eliminating multiple monitor setups, reducing peripheral devices, and enhancing mobility and comfort such as for operators in control room environments. The XR system enhances communications with built-in video, voice, and text chats, as well as screen casting capabilities. The Apple Vision Pro is utilized for the XR system. To execute the XR system, the off-grid power generation system incorporates the supporting intelligent infrastructure; this includes devices such as sensors, smart meters, inverters, and battery storage systems that connect and transmit data via the Internet. The headset of Apple Vision Pro can access the servers of IoT devices through direct applications or by web browser. Once opened, the data windows on server are configured as desired. This data is then analyzed and exported to create real-time grid alerts that produce notifications directly into the operator's vision., The XR system allows for quicker response times and the overall protection of the off-grid power generation, can be easily setup and utilized.

Keywords: Control Room; Smart Monitoring; Extended Reality; SCADA; Remote Monitoring

1. Introduction

Energy is a commodity that is the backbone for modern society [1]. Particularly in the form of electricity; power grids support many aspects of modern infrastructure from everyday luxuries, to life saving institutions and equipment. These grid systems have historically relied on fossil fuels and other non-renewable resources to generate, transmit, and distribute power, which has led to environmental concerns [2]. In order to help offset those concerns while still actively providing power, renewable energy sources are implemented into grid systems.

With the introduction of renewable energy sources, traditional grid systems have been upgraded to optimize the new architecture [3]. Thus, smart grids or intelligent grids systems have become more prevalent; where network connectivity and Internet of Things (IoT) devices are integrated into the grids to support the assimilation of renewable energy technologies [4].

Network connectivity and IoT devices are key components to Supervisory Control and Data Acquisition (SCADA) systems. Power equipment such as smart meters, inverters, sensors, and battery storage systems makes up the intelligent architecture of smart grids and enable grids to transmit data remotely [5]. Data may be transmitted to on-site control rooms or off-site to monitoring devices or software, which are critical for ensuring the efficient operation of the grid.

* Corresponding author: Joseph M. Dowell.

By providing operators with the means to monitor, manage, and control power grids without the need to physically be on-site, it has aided in the reliability and self-healing capabilities of the grids. Important grid data is transmittable to external monitors and other smart devices for remote control anywhere that network connectivity is accessible. These capabilities are part of the infrastructure that allows for the introduction of extended reality (XR), to help facilitate a remote-control room.

This work focuses on a remote-control room using XR for localized grid systems, though similar considerations may be made for expanding traditional control rooms. Due to localized grids occasionally existing in geographically disadvantageous locations, lacking additional resources for a physical control room, or not having the staff for regular operators, a fully remote-control architecture can play a pivotal role [6]. An XR system allows operators to utilize their full environment, 360 degrees, with multiple digital workspaces, and the capability to customize their own workspace. These functionalities give the operator the power to manage digital workspaces wherever they are, whilst still being able to navigate their real-world surroundings, or within a completely digital space. Additionally, with the XR system and headset, operators will be able to receive alerts and notifications directly to their view, and relay those communications to other interested parties.

2. Materials and Methods

2.1. Supporting Infrastructure

In order for an XR system to be viable within the confines of current society, it is imperative that the grid intended to be monitored and managed has the appropriate supporting infrastructure. Currently, society is not and has not been created with augmented reality (AR), mixed reality (MR), or virtual reality (VR) in mind, and that is why supporting infrastructure is paramount. The XR system must be able to reference existing data and systems in order to be of benefit. This is where intelligent IoT devices such as sensors, cameras, smart meters, and inverters that make up smart grid architecture play a key role.

Sensors such as irradiance, temperature, current transformers (CTs), and wind are strategically placed around a grid system to monitor and track critical usage. The sensor data that is collected provides information necessary for regular operation and generates baselines for protective systems. CTs and temperature sensors help to establish thresholds for the protection of sensitive components; whereas wind and irradiance sensors provide data that is essential to determine renewable power generation. Regardless of the sensors function; some may be accessed directly, or they collectively will feed into a device such as a smart meter for monitoring.

The eGauge Pro meter is utilized as the smart meter in this architecture. It is the central connection point for the grid's sensors; it will capture the sensor data, store it, and display it within its proxy server. The built-in proxy server delivers a clear and organized why for operators to monitor, manage, and export data remotely. Operators may also have some control capabilities, depending on their grid infrastructure. From within the meter's proxy server, the operator may configure registers, assign measurement values, and restart the meter remotely. The online proxy server is a key component to corporation with the XR system and other power electronics such as the inverter and the battery storage.

Inverters and battery storage are important power electronic equipment for Photovoltaic (PV) renewable grid systems. They work in tandem to ensure that the solar energy generated is optimized to maintain the functionality of the loads [7]. This is down through the management of the incoming generation, and the stored energy. Whenever the PV arrays are producing enough energy to support the loads, any excess is routed to the battery storage, then when generation is no longer able to meet the demand, the battery storage system will provide supplemental power. These systems are interconnected and typically include an interface for remote interactions, though if they do not, it would be ideal to patch them into the same network as the smart meter for monitoring. From the online applications, the operator may disconnect or disrupt the equipment remotely when necessary.

Collectively, these devices and equipment work together to construct the supporting architecture. Some systems may include these same components or others that serve as supporting architecture, such as cut-off switches or emergency shut-offs that may be incorporated remotely. Regardless, all of the interconnected devices must be installed with connection to a network that will provide remote communication for monitoring; this will ensure the success of the XR system.

2.2. Extended Reality

Extended reality is a general term that encompasses the use of virtual reality, mixed reality, and augmented reality [8]. VR utilizes digital, simulated environments where operators can interact with three-dimensional objects. MR is the intersection of the real and the virtual world environments, allowing operators to engage with objects across both environments seamlessly. Then there is AR, which has some similarities to MR, but it focuses on the presentation of digital data as real-world overlays. An XR system would utilize a combination of the three realities to produce a digitalized control room for remote SCADA functions.

2.3. XR Operation

XR works by allowing the operator to manipulate digital objects within a desired environment. That environment could be real, virtual, or a combination of the two. The manipulation of digital objects is defined by a three-dimensional object's transformation across three axes: x, y, and z. This process is known as the objects translation and it is expressed by the matrix shown in Equation 1. An object's translation (t) is defined by its movement along the three axes, its change in location, but this does not change the size or orientation of the object [Iowa State University Homogeneous Transformations, https://faculty.sites.iastate.edu/jia/files/inline-files/homogeneous-transform.pdf, Last accessed on 05/05/2025] [9].

$$T = \begin{bmatrix} 1 & 0 & 0 & tx \\ 0 & 1 & 0 & ty \\ 0 & 0 & 1 & tz \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

One of the other key components of three-dimensional movement is the rotation. The rotation describes the orientation of an object about a coordinate axis. This concept is similar to that applied to aircraft; it defines the three-dimensional rotation by the object's pitch, yaw, and roll. The "x" axis represents the roll, the "y" axis represents the pitch, and the "z" axis represents the yaw. The matrices shown in Equation 2, Equation 3, and Equation 4 describe the different angles of rotation about the three coordinate axes.

$$R_X(\psi) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos(\psi) & -sin(\psi) \\ 0 & sin(\psi) & cos(\psi) \end{bmatrix} \quad (2)$$

$$R_Y(\theta) = \begin{bmatrix} cos(\theta) & 0 & sin(\theta) \\ 0 & 1 & 0 \\ -sin(\theta) & 0 & cos(\theta) \end{bmatrix} \quad (3)$$

$$R_Z(\varphi) = \begin{bmatrix} cos(\Phi) & -sin(\Phi) & 0 \\ sin(\Phi) & cos(\Phi) & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (4)$$

Another component that is utilized by XR systems is scaling. Scaling deals with the alteration of an object, most commonly by altering the size. Equation 5 displays a matrix that demonstrates how an object is scaled in three-dimensions with respect to each of the axes. Scaling is achieved for a three-dimensional object by translating the object to the origin, scaling the object, and then translating the object back to its original position. This the base concept of how an object would be scaled mathematically.

$$S[x, y, z] = \begin{bmatrix} Sx & 0 & 0 & 0 \\ 0 & Sy & 0 & 0 \\ 0 & 0 & Sz & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

Then, the translation, rotation, and scaling matrices are combined through a combined transformation matrix. The combine transformation matrix is defined by "M" as shown in Equation 6, "M" represents the product of the translation, rotation, and scaling matrices. This function describes how the three aspects of transformation work together to manipulate three-dimensional objects.

$$M = T * R * S \quad (6)$$

XR systems will also utilize some techniques that cameras use, due to their use of visual technology. This includes techniques such as homography, projection, and sensor fusion. Homography defines the transformation that occurs between two planes; this would apply to transformations between the real and virtual worlds [10]. Projection determines how an object is displayed on a surface; in terms of virtual systems, it must be able to project on a variety of surfaces to provide a completely immersive environment. Lastly, sensor fusion refers to the culmination of captured sensor data from the XR system. Sensor fusion utilizes camera, gyroscope, accelerometer, and other sensors to aid XR functionality.

2.4. Extended Reality System

The XR system consists of the use of an XR headset that allows the operator to monitor hands-free. In this work, the Apple Vision Pro is the headset that was used as shown in Figure 1. The Vision Pro utilizes high resolution main cameras, eye tracking cameras, world facing cameras, LiDAR scanner, and sensors that help with lighting and movement. Other headsets with similar capabilities could also be used to support the XR system. The Vision Pro works well for operators due to its use of the Apple visionOS; visionOS is similar to iOS in use, and the general familiarity with the iOS ecosystem contributes to the ease of use [Apple Vision Pro, https://www.apple.com/apple-vision-pro/specs/, Last accessed on 05/05/2025] [11]. Some of the gestures required for operation may require some training, but overall, it functions similar to other handheld smart devices.

Figure 1 Apple Vision Pro Headset

2.5. Control room

An XR control room is a digitalized environment that will allow an operator to perform SCADA duties remotely. For localized systems, an elaborate control room may not be feasible or the most efficient method for management based on grid location. For traditional systems, it would provide operators with more freedom of movement, and the opportunity to utilize more screens. In the XR environment, operators may perform work in their full 360-degree field of vision, they are able to generate more data windows than physical space could support, windows may be scaled, and windows may be moved to different spaces with the operator. Digital workstations or data windows may even be left in a specific space for recall later, or place neared equipment where it will be most beneficial. If desired, operators have the capability to still see and navigate their real-world environment while they manipulate data windows, or they may utilize a VR environment. A VR environment can provide some privacy by disguising the real-world background, especially in cases where an operator is sharing data, and does not want others to see their local environment. The built-in communication features for the headset enable the operator to seamlessly conduct voice/video calls, or even cast their view to another device such as a monitor.

2.6. Operation

With the XR system, when the operator first places the headset on their head, they will be prompted to adjust it to a comfortable setting, it will configure itself to their eyes, and it will scan their hands for accurate gesture recognition. Navigation throughout the headset's interface is down with bodily gestures. The most common are locating items to select through vison (eye tracking), and a tapping together of the index and thumb fingers on either hand. There are other gesture opinions, which individual operators can set to their accessibility needs. Data windows are manipulated, oriented, and scaled by using these same gestures, allowing the operator to set windows at optimal sizes and in ideal locations.

The operator can access the servers for their IoT devices the same way that they are done traditionally; through applications or web servers. In some cases, operators may have to design or create systems or databases for the XR headset to access when connected to a network. From there, the operator can download any native applications, or open a web browser to access the data. Once the necessary windows are open, the operator has the capability to arrange them however they please.

3. Results and Discussion

SCADA is an essential component of smart grid and intelligent power generation. The incorporation of XR grants capabilities that translate the traditional functionalities of a control room to a remote, digitalized environment. These XR capabilities allow the operator to create remote workspaces like the one shown in Figure 2. The windows display usage data in Watts being monitored over the past 48 hours, compared to the measured irradiance in watts per square meter for the last minute accessed. This view is similar to a typical dual monitor setup that someone may have on a desktop, but these windows can be moved around to any ideal location, and the windows may be enlarged beyond that of a physical monitor. Similarly, to an actual workstation, the Vision Pro gives the operator the ability to see their real-world environment around them, and it can also be set to prioritize people if they enter your digital workspace.

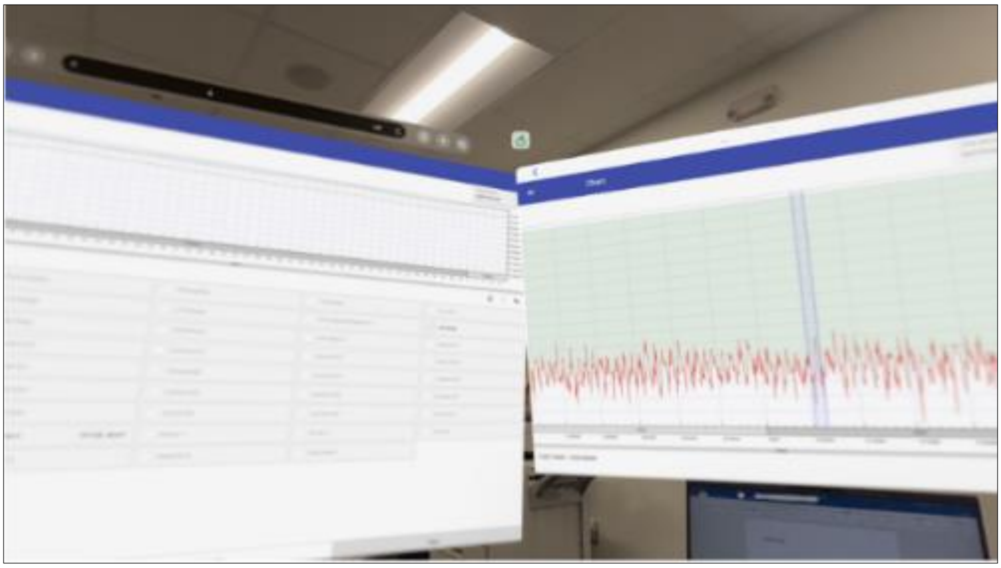

Figure 2 Duel Monitor Remote Workspace with Real-time Grid Irradiance Measured in Watts per Square Meter and Grid Usage in Watts Viewed through the XR System

They may put relevant information adjacent to each other and not have to deal with screen limitations that plague the real-world or referencing multiple screen that may cause strain. The operator has the ability to scale the windows as shown in Figure 3, where they can shrink them down if need be. Shrinking the windows could serve the same purpose as minimizing a window, or making room for other windows within the same space. The scaled workspace displays the solar irradiance for three arrays in Watts per square meter vs the last minute of data accessed.

Figure 3 Remote Workstation of Solar Irradiance for Three Solar Arrays Measured in Watts per Square Meter vs the Last Minute of Accessed Data Scaled Down in XR system

Operators also have the ability to maneuver with the windows in their remote workspace. A window may be selected and carried as the operator moves throughout their environment. Figure 4 demonstrates how the data window for three solar arrays vs the time is migrated to a new location. As shown in Figure 5, an operator may leave the hourly usage data in amperes window in another space to revisit later, and it will still be visible to them through physical structures. When in close proximity, the window appears as if it is still within the workspace, then it may be selected and dragged into any new space.

Figure 4 Three Solar Arrays Irradiance Measured in Watts per Square Meter vs Time in Minutes Window Migrated to a Different Location

Figure 5 Hourly Usage Data Measured in Watts Visible through Nearby Wall after Migrating to a Nearby Room

One of the main benefits for this XR system is the remote monitoring and managing capabilities for localized grids. An operator can be in the office, away from the grid, and still be able to monitor and collect data. Then there is the use of floating keyboards, digital keyboards, and hand gestures that help to alleviate common ergonomic issues associated with traditional monitoring setups. Figure 6 demonstrates this; an operator can keep their hands in a comfortable position and still be able to produce inputs.

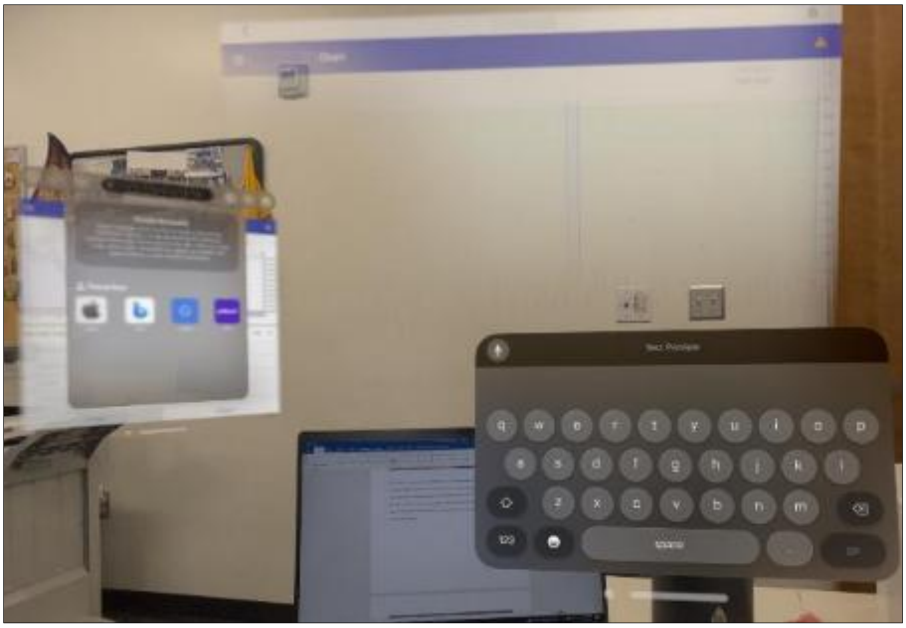

Figure 6 Digital Keyboard in XR System for Inputs within Remote Workspaces with Usage Data, Irradiance Data, and Physical Workspace

Another aspect of this XR system is the that with the scan of the operator's hands and the real-world view, the operator is able to perform live work. As shown in Figure 7, the operator sees a digital representation of their hands as they exist in the real environment around them. This view will allow them to perform live work on the grid in the case that maintenance is required. They can monitor the grid in real-time while performing work with the headset on. Many current systems utilize capabilities like these to train or to specifically identify equipment and their operation throughout the grid.

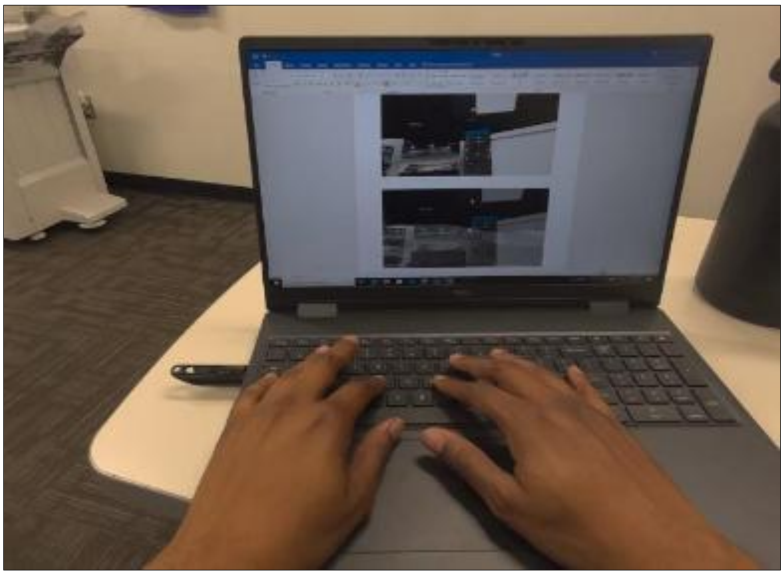

Figure 7 Digital Recreation of Hands for Live Work in Real Environment through XR System View

In the event that the operator is in an environment where they do not wish to share their background while monitoring, they may deploy an environment as shown in Figure 8. This environment is a digital, VR environment that will cover the real surroundings of the operator, but still allow them to navigate the digital workspace within it. The solar irradiance and data usage charts are configured in a stacked dual monitor setup. From this view, operators may cast their workstations to monitors for others to view, share video, or share screenshots without compromising their real-world surroundings.

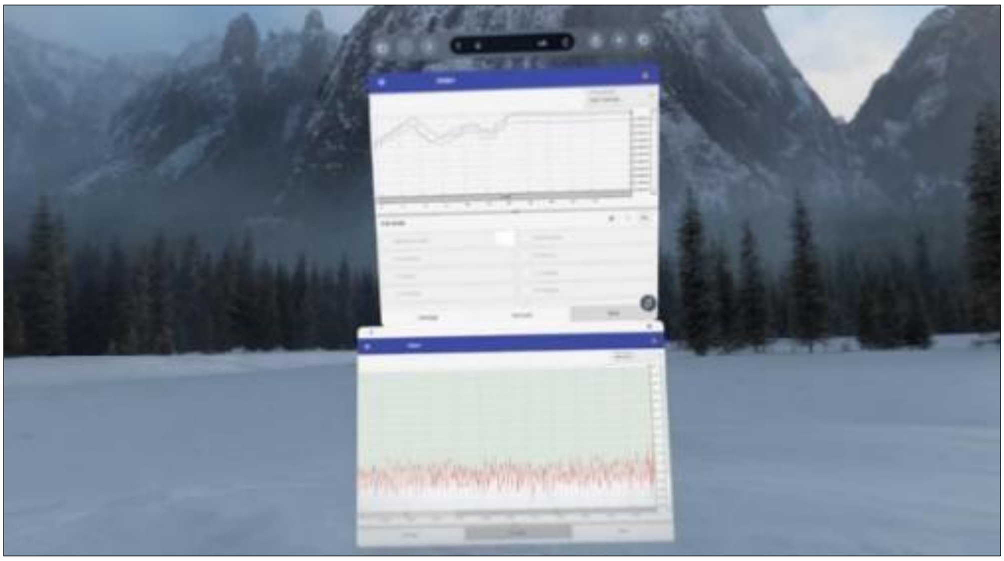

Figure 8 Solar Irradiance and Grid Usage Charts Deployed in Virtual Environment, Stacked Dual Monitor Setup within the XR System

Operators may also integrate security systems into the monitoring. As displayed in Figure 9, security for a grid facility can be monitored from the headset and placed alongside the other data windows. This deployed environment contains multiple windows in the workspace; the security feed, the solar irradiance chart, the grid usage chart, the Sol-Ark inverter grid overview, and a web browser that are all configurable. Operators can maintain full, remote monitoring for their grid systems from anywhere there is network connectivity, and if they have the infrastructure available, they can complete certain actions. For instance, operators may move the security cameras in their environment and they will move in the real-world, they may also speak through the headset and project through the camera's speakers.

Figure 9 Multiple Window Workspace Set in Virtual Environment with Security Feed, Web Browser, Irradiance Data, Usage Data, and Energy Routing in XR System

Another feature that is critical to this XR system is the receipt of grid alerts. Whenever a set grid trigger condition is met, it will prompt an alert notification, which can be sent directly to XR headset. Similar to how notifications are received on a smart mobile device, the notification will appear in view, and then it may be opened for additional details from within the notification banner. Figure 10 displays that live notification as it appears to the operator in the headset, and Figure 11 shows the expansion of that notification. These are security notifications that will alert the operator to motion at the facility and provide details about where it occurred. In Figure 12, it shows an expanded power alert for the grid system, indicating that the power level is below the acceptable threshold. With alerts appearing directly in the operator's view, response time to grid events can be greatly decreased, and major critical events could be avoided.

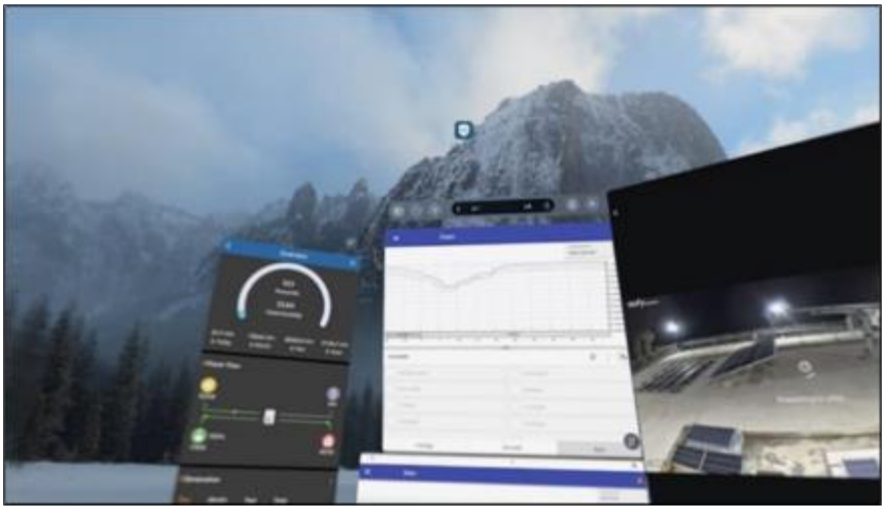

Figure 10 Live Security Notification Icon with Security Feed and Grid data Windows in XR Remote Workspace

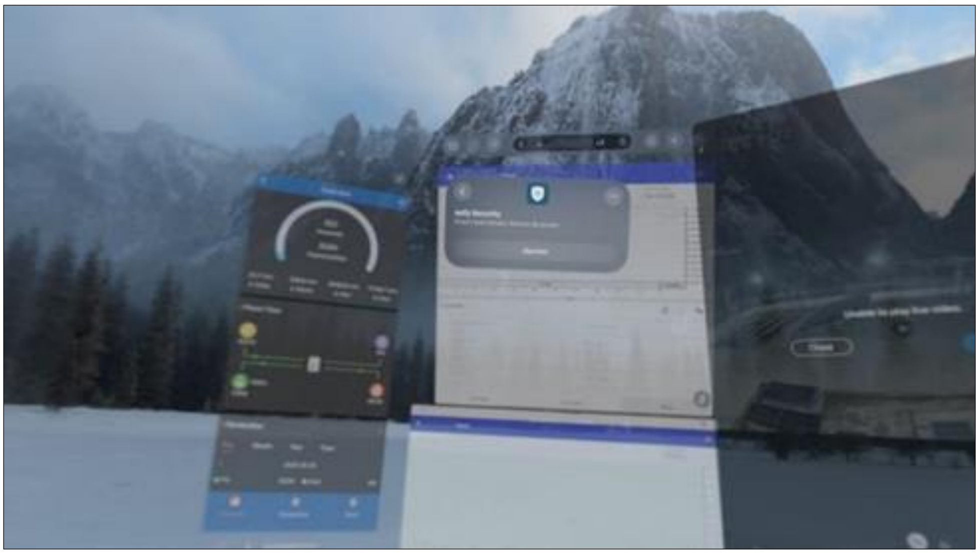

Figure 11 Live Security Notification Expanded for Details in XR Remote Workspace

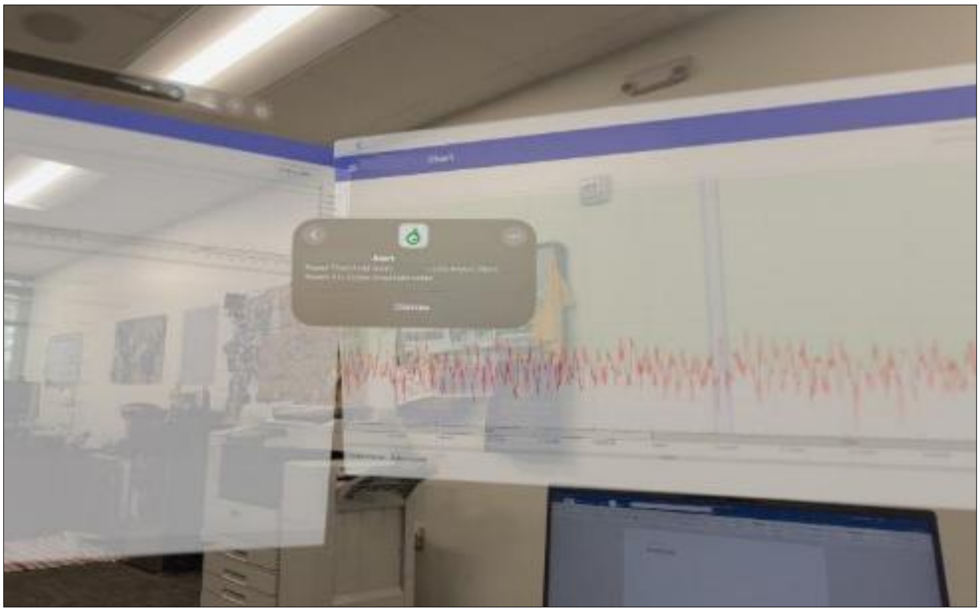

Figure 12 Live Power Threshold Alert with Expanded Details Notification and Grid Data Displayed in the Background in XR Remote Workspace

Despite all of the benefits associated with this XR system and remote SCADA systems, there are some aspects that can be of concern. One that is built-in to the headset and other like it, is foveated rendering [12]. Foveated rendering is a technique that is applied to XR systems that is intended to simulate actual human vision; as a person focuses on an object, the other objects around it become blurry or out of focus. It can go unnoticed during typical operation, but it will be reflected in videos, screenshots, and casts from the headset. There are also concerns with eye strain or motion sickness that some people experience when operating XR headsets. Extended use of these headsets, especially for those that require corrective lenses could lead to discomfort. These are all things to consider when planning to utilize XR systems in a regular capacity.

4. Conclusion

Smart grids are essential to the integration of renewable energy sources to power grid systems. Then, SCADA technology is utilized to monitor, manage, and control smart grids. In order for SCADA to be an effective technique for a smart grid, the grid must have an infrastructure to support it. That infrastructure includes IoT devices and network capabilities that allow for data to be communication and stored remotely. This way, a power grid operator is able to maintain their system without having to be physically on-site.

Remote monitoring is a key component for the optimal operation of a smart grid system. Operators must be able to view and track the performance of the grid in real-time without being directly in contact with the grid. These functionalities are typically performed in a control room, where one or more operators have stationary setups that are dedicated to monitoring of their grid. The issue with this approach is that some localized grids may not have the resources or the people power to have a dedicated control room or for an operator to be stationed their regularly. To alleviate this need, the concept of an XR control room is introduced.

An XR control room will allow for localized grids that fall under this category (and even larger systems that do not) to perform the same duties remotely. Operators are able to access data from their power grid IoT devices and project them within the XR headset. The headset provides the capability to configure their workstation to their liking and organize data in the most efficient manner. The XR system will also allow them to scale the data windows to sizes that appeal to the individual; smaller or larger to depending on the need. Data is mobile, so the operator increases their mobility and is not confined to a specific space while monitoring. The XR system features built-in communication technology for the operator to communicate with other interested parties of the smart grid or they could use traditional methods like email. The XR system may also introduce other ways to collaborate on data, such as with live monitoring between other XR operators, and live stream castings.

These collaborations can help to better protect smart grid systems, as well as the inclusion of security camera feeds, and alerts. Operators may view security feeds as part of their remote workstations, and receive notifications about unauthorized access. Operators will also receive notifications for grid alerts that indicate whether there is an event occurring within the grid or the possibility of an event. With real-time notifications in the headset, response time can be reduced, and overall grid protection will be enhanced.

An XR SCADA system offers a number of benefits to remote monitoring and improvements to traditional control rooms, though it is not without fault. Like many networks driven devices, it requires a constant and reliable Internet connectivity to be functional, and that could also make it susceptible to intrusion. There are also some people that do experience discomfort from the headset digital view, especially after extended usage. Even more commonly, the foveated rendering technique may make the capture of XR data difficult to interpret for outside parties due to a blur effect whenever the operator is not specifically focused on that data. Despite these challenges, the XR system could help to change the traditional control room experience.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] I. Trunina, M. Bilyk, A. Chumakova and O. Usanova, "Energy Management for the Development of Smart Regions," 2022 IEEE 4th International Conference on Modern Electrical and Energy System (MEES), Kremenchuk, Ukraine, 2022, pp. 1-5, doi: 10.1109/MEES58014.2022.10005643.

[2] C. Li et al., "A Study of Environmental Protection Planning Method and Environmental Risk Assessment of Regional Power Grid," 2022 IEEE 2nd International Conference on Power, Electronics and Computer Applications (ICPECA), Shenyang, China, 2022, pp. 107-111, doi: 10.1109/ICPECA53709.2022.9719062.

[3] R. Piacentini, "Modernizing power grids with distributed intelligence and smart grid-ready instrumentation," 2012 IEEE PES Innovative Smart Grid Technologies (ISGT), Washington, DC, USA, 2012, pp. 1-6, doi: 10.1109/ISGT.2012.6175653.

[4] S. Avinash, J. C. Vinitha, S. S. Dharinya, V. Samuthira Pandi, L. P. J and J. S, "The Future of Smart Grids: Revolutionizing Energy Distribution with Advanced IoT, and Renewable Integration," 2024 5th IEEE Global Conference for Advancement in Technology (GCAT), Bangalore, India, 2024, pp. 1-6, doi: 10.1109/GCAT62922.2024.10924087.

[5] A. B. Abdulsalam, H. A. J. Alsaadi and Z. Hamodat, "Control And Management of Solar PV Grid Using Scada System," 2022 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA), Ankara, Turkey, 2022, pp. 1-5, doi: 10.1109/HORA55278.2022.9799994.

[6] Z. Guo, W. K. C. Wong, K. S. Myo and W. X. Choong, "Multiple Screen Control Application with Facial and Gesture Recognitions in a Manufacturing Control Room," 2020 15th IEEE Conference on Industrial Electronics and Applications (ICIEA), Kristiansand, Norway, 2020, pp. 48-53, doi: 10.1109/ICIEA48937.2020.9248353.

[7] V. R. Chowdhury, M. A. Chaaban, S. Essakiappan, M. Manjrekar and Y. Xue, "A grid connected PV micro-inverter with optimized battery storage utilization," 2015 IEEE Energy Conversion Congress and Exposition (ECCE), Montreal, QC, Canada, 2015, pp. 3455-3461, doi: 10.1109/ECCE.2015.7310148.

[8] J. Singh, G. Singh, R. Verma and C. Prabha, "Exploring the Evolving Landscape of Extended Reality (XR) Technology," 2023 3rd International Conference on Smart Generation Computing, Communication and Networking (SMART GENCON), Bangalore, India, 2023, pp. 1-6, doi: 10.1109/SMARTGENCON60755.2023.10442251.

[9] Jia, Yan-Bin, “Homogeneous transformations,” Iowa State University. (2020). https://faculty.sites.iastate.edu/jia/files/ inline-files/homogeneous-transform.pdf. Accessed 5 May 2025.

[10] S. P. Bangarashetti and P. N. Kunchur, "Image Mosaicing Using Homography Estimation," 2020 IEEE International Conference for Innovation in Technology (INOCON), Bangluru, India, 2020, pp. 1-4, doi: 10.1109/INOCON50539.2020.9298448.

[11] Apple. “Apple Vision pro - Technical Specifications.” Apple, 2024, www.apple.com/apple-vision-pro/specs/. Accessed 5 May 2025.

[12] H. Zhang and C. Peng, "Foveated VR Rendering System for Large 3D Meshes," 2025 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), Saint Malo, France, 2025, pp. 1246-1247, doi: 10.1109/VRW66409.2025.00269.