AUGMENTED REALITY IN GRID OPERATION A NEW APPROACH TO SUPPORT MANUAL SWITCHING OPERATIONS

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ABSTRACT

This paper describes an Augmented Reality project, which was implemented to evaluate the usefulness of this emerging technology in the context of switching operations. Data system prerequisites are described as well as functionalities of the AR application. The project demonstrated that there are considerable potential benefits with regard to improving efficiency of work processes and occupational safety, but also showed some existing limitations of the technology such as trade-offs in user comfort and current technical restrictions.

INTRODUCTION

Augmented and virtual reality are buzzwords, which are often mentioned in the same breath with Industry 4.0. In an augmented reality (AR) application, the real-world environment is enhanced with virtual content that becomes an integral part of the user's experience, whereas in a virtual reality (VR) experience, the user is completely immersed in a virtual, computer-generated environment. Both AR and VR environments are highly interactive, allowing users to bring up or hide visual or auditory information to perform tasks, give commands or gather data. Thus far, AR technologies have widely been used in education, the entertainment and gaming industries. In recent years, other sectors have started to explore the potentials of AR, for example, to improve work processes and occupational safety.

The utility sector, in particular, has been experiencing a trend to higher complexity, and even standard operations are becoming increasingly difficult to manage without the support of new technological aids. AR technology, though it is still in its early stages, does have the potential to significantly improve processes in this area [1, 2].

The following topics are potential practical AR applications during switching operations:

- A guided workflow, offering sequential processing of executable switching tasks
- Visualizing of hazard alarms
- Displaying safety instructions
- Sending out a digital emergency call
- Direct interaction with the grid control center to improve communication

Despite the identified potential of AR technologies, the modes for interacting with virtual objects in an augmented reality space are still not fully optimized. Currently, interaction takes place either by hand gestures, voice input or directed gaze. Even the haptics and the handling of data glasses, such as the Microsoft HoloLens®, feel unfamiliar and should be evaluated within a real use context.

To get a better understanding of the potential benefits and limitations of AR technology, the KNG-Kärnten Netz GmbH (KNG) and Omicron Electronics GmbH (OMICRON) conducted a joint AR pilot project.

KNG is an Austrian DSO with a peak load of 878 MW and a distribution volume of 4 TWh. The KNG operates a high-, medium- and low-voltage grid of approximately 18.000 km in length. The utility manages 46 substations at a 110-kV voltage level and 7.300 MV/LV transformer stations to provide energy for more than 300.000 customers.

OMICRON electronics GmbH is a globally active, medium-sized company headquartered in Klaus, Austria. The company manufactures testing and diagnostic equipment for assessing the condition of primary and secondary equipment in electrical power engineering.

The primary goal of this project was to evaluate AR technology with respect to improving the manual switching processes for field engineers. The aim was to carry out an assessment in the following areas:

- technical feasibility and limitations
- user acceptance
- improvement of occupational safety
- enhancement of efficiency
- delivering interactive work instructions

Furthermore, the usability of the Microsoft HoloLens® glasses for field engineers was evaluated with a field test in the training center of the KNG [3].

SYSTEM REQUIREMENTS

A basic requirement for the integration of AR technology into the company's processes is an extensive, high quality data basis. During the last decade, the KNG proceeded with a step-by-step implementation of an integrated data management system [4, 5, 6]. Therefore, interfaces between various applications like the SCADA/DMS system, the geographical information system (GIS), the enterprise resource planning system, (ERP/SAP) and the workforce management system (WFM) were set-up, as shown in Figure 1. The main aim was to establish a process-orientated data-exchange between these different digital platforms to optimize distribution grid operations within the utility. As a result, the data generated during an outage or a planned maintenance activity are available to the various applications in the system in near real- time.

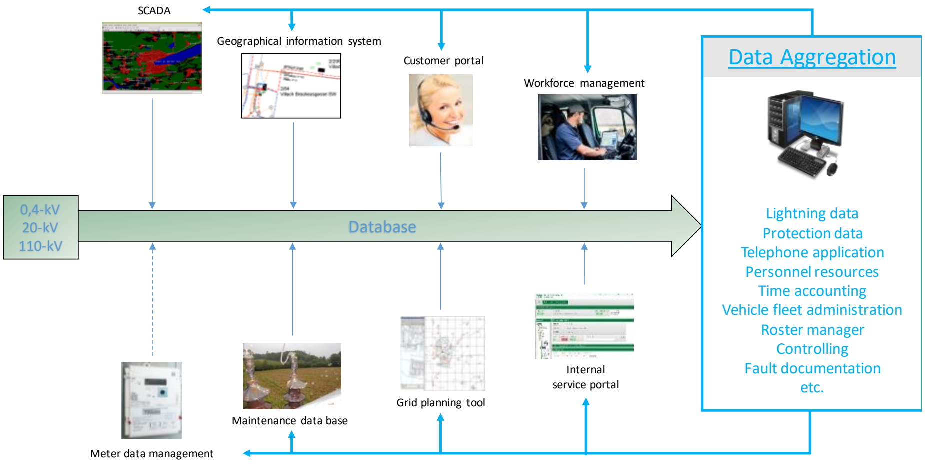

Figure 1: Data management system in KNG

INTERFACES AND SUPPORTED DEVICES

The goal of the AR test application was to evaluate the improvement potentials of this technology with regard to the work processes during switching operations. A special focus of the project was the communication between the grid operators in the grid control center and field engineers. The investigation focused on reducing the need for personal interactions, while at the same time, striving to increase work safety. Therefore, two different user interfaces to the AR system were developed to serve the special requirements of both user groups.

<u>Central grid control center staff</u>

Working environment: Office
End devices: PC (DMZ)
Implemented functionalities:

- Direct communication with field engineer (audio/visual)
- Generation and administration of work packages for switching operations (switching procedures)
- Assignment of switching procedures to the authorized switchgear operator
- Authorization of switching procedures
- Live visualization of work progress and status update

<u>Authorised field engineers (switchgear operators)</u>

Working environment: KNG Training Center
End device: HoloLens®, Tablet
Implemented functionalities:

- Direct communication with grid control center operator (audio/visual)
- Selection and acceptance of an assigned switching procedure
- Retrieval of safety-related warning notices
- Release of individual switching procedures and feedback on successfully completed work tasks
- Verification of switching states

<u>Interfaces to third-party systems</u>

The application was designed to make data from various KNG systems available to the switchgear operator in the field, as well as transmit relevant data from the AR application to various third-party systems. In a live-operation scenario, an authorised switchgear operator could call-up and display additional information from the WFM, NLS, GIS and the "Operational Service Portal".

IMPLEMENTATION

Description of KNG training center

KNG operates a training center, which is an ideal environment for a pilot project to evaluate AR technology as it offers a safe working environment and is well connected in terms of infrastructure (see Figures 2 and 3). The facility is used for the training and certification of switchgear operators. Technicians from the KNG as well as from other companies have the opportunity to learn and practice the operation of all variants of switchgear in the 20-kV grid.

In addition, the training center is used for the following purposes:

- Research and development of new technologies and their integration into existing work processes
- Training purposes (autonomous operation in a test environment) as well as training for external field engineers
- Teaching the basic functions and configuration of grid equipment
- Simulation of fault sequences

Figure 1: KNG training center

Figure 3: KNG training center

Generating work packages for switching operations

For the AR project, a fictitious grid was set-up in the training center - using the available switchgear on-site - and was visualized in the SCADA system. This allowed the generation of switching procedures for the training center from the SCADA-DMS environment.

A switching procedure is a defined working order, which regulates the sequential work tasks required to carry out switching operations on specific types of equipment. In the case of planned and unplanned operations in the 20-kV grid, the individual work steps are defined by the staff in the grid control center and are passed on to the authorized switchgear operator in the field, who performs the required tasks. Due to KNG-specifications, the field operator needs to keep the grid control center operator updated on his activities at all time to ensure that the switching state in the field is always identical with the switching state in the SCADA environment. At the same time, the SCADA system monitors the supply status of customer facilities in the background and reports given anomalies. When an anomaly is detected, fully automated control processes for grid restoration are initiated (e.g. fault visualization, IVR manager) [6]. Subsequently, the SCADA forwards the newly generated work packages digitally to the grid control staff and the AR application. On this basis, the AR application in turn generates a working package, which specifies the sequential tasks required to perform the necessary switching operation. Once the grid control operator has authorized a switching procedure and set it into an active state, it becomes available on the mobile AR devices (Microsoft HoloLens and/or tablet).

Selecting switching procedures and documents

The switching procedures are displayed on the HoloLens and on the tablet as work packages. The field engineer can select a switching procedure via the HoloLens using voice commands or gestures. Once the selection has been made, detailed information of the switching procedure is displayed:

- switching procedure number
- status of the switching procedure
- start and planned end of the switching operation
- affected grid components
- affected grid customers
- fault history
- relevant documents

For additional information, the user can retrieve documents assigned to the switching procedure by voice command. He can scroll through the list of available files and select individual documents by gesture control. The selected file can then be placed in the room by the user. To ensure readability, the document can be moved and enlarged. In this way, the field engineer can easily retrieve and visualize additional information regarding the current switching operation and the system (e.g. circuit diagrams, GIS detail images) as well as historical data for the station (e.g. malfunctions and maintenance measures).

Completing tasks

Once the authorized field engineer has selected the active switching procedure for the station and has viewed all related documentation, he is ready to complete his first task. For this, the field technician is directed by the AR application to the correct location of the first step in the work package by means of a directional arrow and a distance indicator. A three-dimensional hologram marks the switchgear to be operated, as shown in Figure 4 and Figure 5.

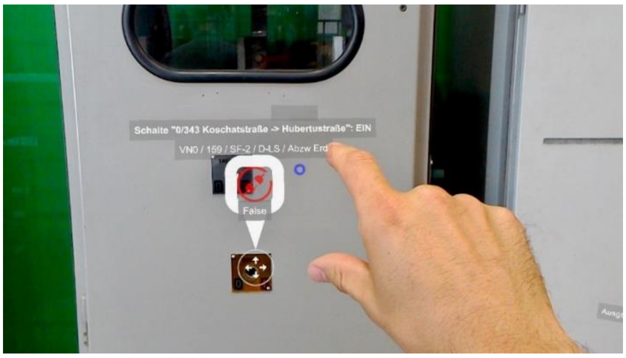

Figure 4: Visualization of individual tasks

Figure 5: Field engineer with HoloLens

This indication virtually eliminates the possibility that a field technician mistakenly operates the wrong equipment. Once the operator is in front of the switchgear, the hologram disappears, and the task can be carried out. After the switching action has been executed, the completion of the task is confirmed digitally by means of a hand gesture. This action activates the next step in the sequence. Thus, the field engineer is guided through the switching procedure and can, with the support of the AR application, proceed independently through the individual steps in the work package. The grid operator in the grid control center can monitor and track the progress of the field engineer in real-time.

Once all required tasks have been completed, the field engineer requests a working permit for the defined disconnected grid section via the AR application. The operator in the control center confirms this request. As soon as the field engineer receives the working permit confirmation, the work on the released equipment can be started.

All executed switching tasks, including time stamp of the execution, are recorded in a history for later retrieval and statistical purposes.

One current technical limitation was the need to physically position the tasks on the respective switchgear in the training center in advance. However, with a further development of the AR technology towards automatic pattern recognition, including automatic identification of the equipment, the future practical use of this technology is becoming more and more probable.

OCCUPATIONAL SAFETY

An emergency stop alarm can be triggered via the grid control center directing the field engineer to leave the station (e.g. in the event of an earth fault). Currently, the grid operator must manually trigger this alarm, but if a direct interface with the grid control system could be implemented in the future, this could also be triggered automatically. The emergency stop alarm is displayed prominently in the field of view of the AR user and can be acknowledged by the user.

In the future, the AR user could also trigger an emergency alarm and send an emergency call directly to the grid control center, for example via voice command.

REMOTE SUPPORT

Direct communication between the grid operator in the grid control center and the AR user is possible via the Skype for HoloLens application. Additional parties, such as technical support personnel, can also be brought into the call. During such an audio-visual Skype session, the participants can share all visual content (real and augmented) and see exactly what the field engineer sees. Various interaction tools allow the session participants to point to or mark viewed components digitally. This leads to improved communication and more targeted problem solving.

CONCLUSION

This pilot project was a first step towards applying AR technologies in an electric utility setting. Even though this is still a relatively young technology, this evaluation showed that the AR-technology has the potential to optimize work processes, enhance efficiency and increase occupational safety. Specifically, the project demonstrated the following potential benefits:

- Improved coordination between grid control center staff and field engineers (real-time status updates)
- Less communication via telephone required
- Improved support capacities via remote support
- All required information (documents etc.) readily available
- Reduction of potential for human errors (no operation of wrong equipment or skipping or mixing-up steps in the sequence)
- Improvement of occupational safety aspects (hazard warnings, emergency calls and protocols)

However, there are still some drawbacks and limitations that need to be addressed before this technology can be applied and integrated in a real-life work process. The following issues have been identified:

- Unfamiliar operation concept and user control (gesture, gaze and speech)
- Speech control currently only available in English
- Practicality and comfort issues regarding wearing the Hololens®. (In time, the device gets heavy and warm, and it restricts the field of vision somewhat.)
- Limited battery life
- High performant data connection and network connection necessary
- Limit due to manufacturer- specific development environment

In order to make tomorrow's technology usable, the commitment to collect and digitally document high-quality data (test and measurement data) from all assets is a key aspect. With proprietary data management systems, care must be taken to ensure that they can be easily integrated into the heterogeneous utility IT landscape.

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