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Foreseeing the Potential of Virtual Reality in Nuclear Power Plant Field Operator Training

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ABSTRACT

Advanced technologies such as virtual reality and augmented reality have found their way to a variety of industrial applications and settings. The nuclear domain does not make an exception, thus there has been an increasing interest to investigate how these technologies could be of use in different operative activities in nuclear field, one of which could be the operator training. In this paper, we concentrate on the training of field operators and especially, how virtual reality could facilitate and advance this process. We have conducted an interview study about the training of field operators in two Finnish nuclear power plants. As results, a summary is made on organization of field operators' training and what are the benefits and limitations of the current practices. We also report how the field operators foresee the potential of virtual reality in their training and finally provide some design implications for developing such training solutions.

Keywords: Nuclear power plant, Field operator, Training, Virtual reality

INTRODUCTION

New advanced technologies such as virtual reality (VR) and augmented reality (AR) have made their way into variety fields of industries. These technologies promise to augment and enhance the industry operations in many ways, for example, by helping to gain better understanding of the product/system under development (Hjelseth et al, 2015) or enabling online guidance and decision support on specific work situations. The possibilities of VR&AR have also been studied in nuclear power plant (NPP) context. For instance, VR has been applied successfully in ergonomic studies in designing control room spaces and facilities (Gatto et al, 2012; Meunier et al, 2018; Zamberlan et al, 2012). Furthermore, VR use in visualization of radiation have been studied with the aim to facilitate planning of maintenance activities, and thus enable to minimize the personnel's time spent in contaminated spaces (Mol et al, 2008; Nystad et al, 2011). The results of these studies have already indicated that with the use of VR it is possible to positively influence on the

Table 1. Data collection in the two NPPs.

Plant	Number of interviewees	Work experience (years)
Loviisa NPP	5	(2-30)
Olkiluoto NPP	6	(3-30)

reduction of dose measures when compared to activities without VR support. Furthermore, VR simulations has also been developed in the context of control room verification and validation activities (Bergroth et al, 2017; Dos Santos et al, 2009).

One potential application area for VR in safety-critical system operation and in the nuclear domain is operator training (Andres et al, 2016; Koskinen et al, 2021; Louka et al, 2001; Yue et al, 2016). Nowadays the operator training is organized most often as classroom and simulator training in physical training simulator environments. New advanced technologies may enable to enrich the conventional training facilities so that, for example, more hands-on training of teamwork and collaboration between the control room and the field operators becomes possible (Koskinen et al, 2021). The benefits of VR in training of operators and maintenance personnel in nuclear context can be great as in VR the work tasks can be trained in a safe environment without real-life time restrictions and repeatedly as many times as needed.

We have conducted an interview study about the training of field operators (FOPs) in two Finnish NPPs. Altogether 11 interviews were carried out with personnel responsible of field operations and the training of field operators. We also report how the FOPs foresee the potential of VR in their training. Furthermore, suggestions are provided on concrete VR applications that may benefit the training and work of FOPs and present some practical design implications for developing VR-based training.

DATA COLLECTION

The interview study was conducted in two Finnish nuclear power plants, that is, Loviisa NPP and Olkiluoto NPP. Altogether, 11 (five from Loviisa NPP and six from Olkiluoto NPP) field operators were interviewed (Table 1).

The form of the interview was structured and, questions were made under four specific themes: 1) Field operator work, 2) Collaboration, 3) Training, and 4) Possibilities of VR.

Due to the Covid19 pandemic situation the interviews were conducted remotely through a Microsoft Teams application and the duration of the interviews were approximately one hour. The interviews were audio recorded and transcribed for further analysis.

RESULTS

Field Operator Work

The work of the field operator consists of process control and monitoring, routine field inspections and periodical testing. FOPs work mainly in pairs, however, some of the work is done alone, for example, field-inspection responsibility areas are shared between the partners. In addition to routine inspections, the field operations include process separations and returns, periodical testing of emergency systems and valve operations.

FOPs work in close collaboration with the control room operators in a daily manner. All the tasks are distributed by the control room operators, and mutual situation awareness is maintained by reporting significant phases of any operation to the control room.

The work of the FOPs includes challenges related to complexity, uncertainties, and dynamicity. Extensive job description, variety of tasks and vast field of operations increase complexity of the work. For example, in Olkiluoto NPP, certain external facilities at the NPP area are included in the responsibilities of the FOPs. The extensiveness of the field also sets uncertainties, as it is sometimes a challenge to navigate to the right component in narrow places. Hot temperatures and steam are one of the hazards of the work which add uncertainty. During revision, the working pace is more hectic compared to the normal operation, adding dynamicity. Distances in the facility area can be long, and thus it is time-consuming to travel between various locations.

Training

In both NPPs, it was typical that the backgrounds regarding the professional training of FOPs varied a lot. Thus, there was no individual line of education or school that would have directly prepare for FOP's profession and tasks. Of course, it was recognized by the interviewed FOPs that a certain extent having a technical background (e.g., electrician or assembly worker) may be helpful in acquiring the tasks and knowledge required in FOP's work.

Both NPPs have their own basic training programs for FOPs (Table 2). There are many similarities between the training programs but also some plant-specific differences. In both NPPs, the training starts with an introductory training in which issues such as important plant information and organizational guidance and occupational safety is gone through. This is followed by a more theoretical training of plant systems and equipment in Loviisa NPP that takes altogether approximately two months. In Olkiluoto NPP, there is a short on-the-shift training period for FOPs before they engage technical training of plant systems and equipment. After the training of the plant systems and equipment in both NPPs, the FOPs are going through a longer period of time on-the-shift training. In Loviisa NPP, a specific study plan is drafted for each FOP individually that acknowledges the vacancy-specific responsibilities and learning goals, that is, the primary and secondary side FOP tasks. In the end of the basic training, a test is organized for the FOPs. In Loviisa NPP, the final exam is realized as a written exam whereas in the Olkiluoto NPP, the final exam includes a field inspection round together with the division manager and the shift supervisor.

In both NPPs, the FOPs also participate in yearly refresher training. The content of this training may vary depending on the identified training needs in each plant. In practice, it may be training related to some new plant systems or equipment or procedures and safety guidance that have been updated.

Table 2. A general overview of the FOP training programs and practices.

Form of training	Loviisa NPP	Olkiluoto NPP
Basic training	Introductory and theoretical training on electricity production and plant systems and equipment (duration approx. 2 mo.) Decision on the coming vacancy (primary or secondary FOP based on demand) On-the-shift training on guidance of experienced FOP and based on individual study plan (approx. half a year) A final exam (written format) *Methods/materials:* group lectures, design documentation and procedures, individual study plan	Entrance training (e.g., plant introduction and occupational safety) A short on-the-shift training period Technical training on plant systems and equipment On-the-shift training period A final exam in which field inspection round is executed with a division manager and a shift supervisor *Methods/materials:* group lectures, design documentation and procedures
Refresher training	6 d/year, from which 4 d lectures 2-4 d simulator *Methods/materials:* Process models, equipment manuals, procedures, simulator etc.	6 d/year, from which 6 d lectures (not established practice yet) d simulator *Methods/materials:* Navis-system, procedures

The FOPs also participate in simulator training together with the control room operators. In Loviisa NPP, this form of training for FOPs (i.e., simulator training) has already been well established practice many years whereas in Olkiluoto NPP, the FOPs have just in the resent years took part in the simulator training. In addition to the official yearly training days, in both NPPs, FOPs have self-study materials that they can independently access and study according to their own preferences.

Benefits and Limitations of the Current Training Practices

The interviewed FOPs were inquired what the benefits and limitations are they experience in their current training practices.

In Loviisa NPP, the FOPs generally thought that learning by doing was effective way of learning their work tasks. Being involved in the simulator training with control room operators were conceived a good practice so that also those FOPs that were not usually spending much time in the main control room had a possibility to see that side too. However, into the way how the simulator training was organized now, that is, the FOPs mainly followed the simulator run from a side and went through the related procedures was hoped improvements. Particularly, the FOPs wished that they could be more actively involved in the simulator run (i.e., carry out the tasks assigned to them). Another issue related to the training and knowledge management was that the FOPs thought that some specific information and knowledge was hold by too few people and, for example, in a situation in which this kind of person was retiring important information from the organization may have been lost. The FOPs also thought that improvements could be done in training to use the new equipment and systems, and, for example, it would be beneficial to be able to follow the installation work and testing of the new systems.

In Olkiluoto NPP, the FOPs wished that the refreshing training program would include more material and content that would be specially tailored for the needs of the FOPs. In addition, they hoped more hands-on training in the field as there is always the possibility that while independently going through the documents and written instructions some things may be misunderstood. Moreover, training of new equipment and systems was hoped to be more even-handed meaning that also making sure the other FOPs that were not in the shift at the time of the installation and commissioning of the equipment can get the training for the use of the system. According to the FOPs now it was relied too much on that the colleagues were passing the relevant information about the new equipment to the others. In Olkiluoto NPP, they had a new system called Navis in use that included photos from the plant's room spaces and equipment that the FOPs could use independently to study and rehearse. The Navis system was experienced as a good additional source of information by the FOPs and they used the system to, for example, review spaces that were not accessible during normal operation due to radiation.

Possibilities of Virtual Reality in Field Operator Training

In both NPPs, early attempts to add virtual reality to the field operator training are already under development. In the more advanced example from Loviisa, FOPs participate control room operators' simulator training using a VR environment created with a 360-footage from the facility. The VR environment is connected to the simulator, and the FOP performs determined operations in an adjacent room. There is no means to communicate with the control room operators through the VR application, and thus in these simulator training sessions, the instructor was needed to deliver messages. The application includes VR-glasses, that are lacking in the other, less developed VR environment, that is used in the other NPP. In the latter case, the VR environment is merely an open database of 360-pictures for self-learning purposes. In both NPPs, the future objective is to use VR environment to improve FOPs active participation in the simulator training.

The interviewed FOPs saw potential in applying VR in their training and identified several opportunities of VR for training purposes related to **practicing certain tasks** and **rehearsing premises**. Tasks that could be practiced in VR environment included demanding tasks as well as tasks that were not possible to practice during normal operation. The VR was seen useful in presenting the facility premises to new field operators during their training. Experienced operators could also use the application to rehearse locations of valves in rooms with high radiation levels. The VR could also be used in route planning to certain rooms. Altogether, VR training was believed to reduce radiation exposure and increase the usefulness of simulator training.

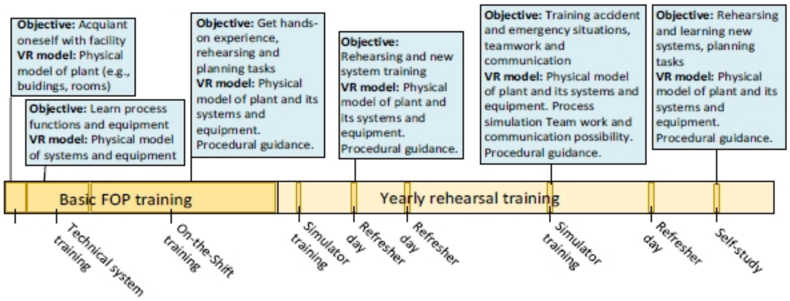

Figure 1: Mapping of VR-based solutions with FOPs training program.

The interviewed field operators identified several elements necessary for the design of the VR environment. Realistic modelling of room spaces with relevant details, pathways with possible obstacles such as fire or steam and system identification codes was considered important.

DISCUSSION AND CONCLUSIONS

An interview study in two Finnish NPPs was made about the FOPs training and how VR could enhance the process of acquiring the skills and knowledge needed at their work. Generally, in both NPPs, the FOPs thought that their training program had developed to a favorable direction during the years. The training had become more systematic, and FOP specific content had been developed for the training.

VR-based solutions were seen to provide new possibilities in training. The characteristics of the VR training solutions that may appropriately support learning may change over the course of the training program and specific learning objectives set in each point of the program (Figure 1).

As already discussed in the previous section, both NPPs already have some VR-based solutions in use and the FOPs has got their first experiences on the benefits of these technologies in the training. However, future work on developing VR-based training systems in NPP context would include, for example, extending the scope of the VR-models, adding new functionalities (e.g., procedures or step-by-step guidance) and collaborative qualities. In addition, it would be necessary to conduct comparative studies in which the traditional training methods and their effectiveness compared to the VR&AR -based training would be explored as only few studies have focused on this in safety-critical operations. However, in the end, it might be that the most suitable setup for training would be a combination of these two training mediums. Finally, based on our interview study the FOPs generally had positive attitudes towards the VR in their training that suggest that these systems are worthwhile to continue develop.

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