30th NENE 2021
September 6 - 9
BLED-SLOVENIA
International Conference Nuclear Energy for New Europe

Remote research reactor exercises during pandemic induced lockdown

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ABSTRACT

The COVID-19 induced restrictions have prevented reactor physics students from attending in-person reactor physics exercises which are a vital part of their education. Jožef Stefan Institute has organized remote exercises with the help of off-the-shelf technology, including multiple videoconferencing setups, remote desktop software, portable cameras, a dome camera, shared spreadsheets, and a common whiteboard. The students were encouraged to actively participate in the exercises by giving instructions to the reactor operator, asking and answering questions, logging data, operating digital acquisition systems, and performing analysis during the exercise. The first remote exercises were organized as a five-day course of experimental reactor physics for students from Uppsala University. The feedback was collected after the course using an anonymous online form. The aspects being evaluated included the technical content, quality of material, performance of the individual lecturers and the quality of the remote session. In general, the response was overwhelmingly positive, with most questions with a rating scale answered with "excellent".

1 INTRODUCTION

The Jožef Stefan Institute (JSI) regularly organizes trainings [1, 2] for local and foreign students of nuclear engineering and related sciences. The exercises are very valuable for the students because they give them the opportunity to perform practical experiments on a working nuclear reactor, and in some cases represent the only link between theory and experimental research. Travel restrictions in 2020 due to the COVID-19 pandemic prevented foreign students from traveling to Slovenia, and the closure in spring 2020 meant that practical exercises at the reactor were not possible at all. This paper describes some innovative solutions that were implemented to allow participants the closest possible approximation of in-person exercises given the restrictions. This paper presents a five-day distance learning course in experimental

Figure 1: The students are communicating with the reactor operator and the lecturer, observing the operator movements and controlling a shared spreadsheet.

reactor physics organized for Uppsala University using commercially available equipment. The performance of the course was evaluated by an anonymous online survey in which all students and their mentors participated. The organizers asked both open questions and questions that were answered using a rating scale. In this paper we focus on the experimental reactor physics course organized for Uppsala University and its implementation, followed by an evaluation of the course and an outlook on future improvements.

2 TECHNICAL EXECUTION

2.1 On the reactor side

The main means of communication were personal computers with the video-conference software Zoom. They are marked with ”2” on photo Figure 1. The portable cameras, marked with “5.” in Figure 2, could be taken into the reactor hall by the instructors to take a virtual tour, show the experimental setup or other activities at the reactor, such as the removal and re-installation of the neutron source during criticality approach. In addition to the smartphone and PC cameras, a dome camera (”1.” in Figure 3) in the control room and a camera installed above the reactor core (Figure 7) could be viewed and controlled by the students via the remote desktop software.

Students could point the dome camera at any area of the control room and zoom in or out to view the lecturer, the reactor operator’s actions, or the nuclear instrumentation. The dome camera location is visible in Figure 3. The camera mounted above the reactor is used to see the bubbles being blown through the reactor core, the neutron source being removed, or the Cherenkov radiation Figure 7. The dome camera and the camera mounted above the reactors were also both viewable from the television in the control room (marked “1.” in Figure 1 and Figure 3).

The remote desktop software was also used to control the digital acquisition software,

Figure 2: One of the instructors is using a smartphone with video-conference software as a portable camera.

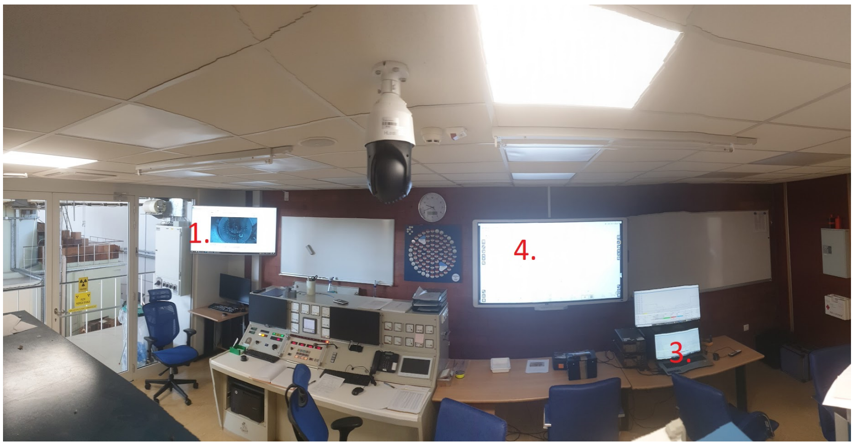


Figure 3: The dome camera is mounted on the ceiling and positioned so it can see the reactor control panel, nuclear instrumentation readings and a lecturer in front of the shared whiteboard

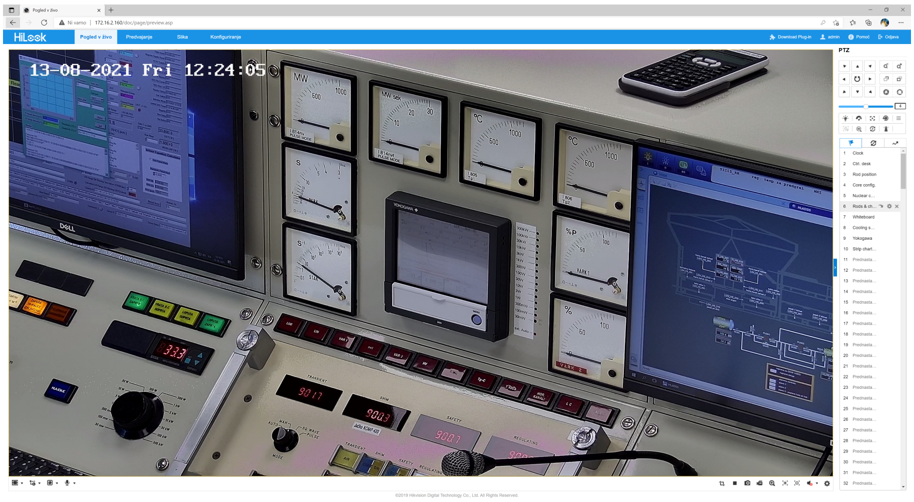
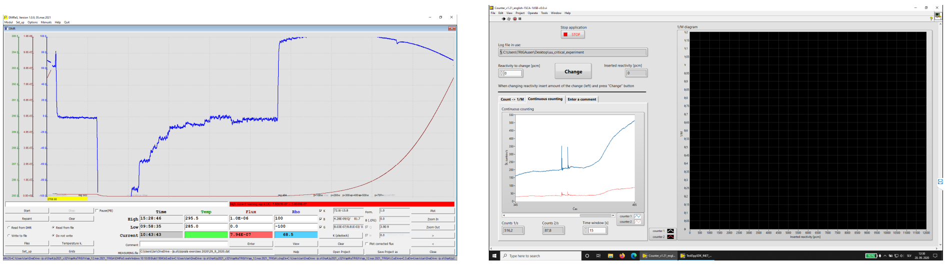


Figure 4: Dome camera pointed to the nuclear instrumentation. It could be remotely moved and zoomed-in to any point in the control room by using controls on the top right corner. Predefined positions (such as instrumentation and rod positions) could be selected in the table on the right side of the image.



(a) Digital Reactivity Meter (b) Digital acquisition software

Figure 5: Software used during the ”criticality approach” exercise via remote desktop by students.

the shared whiteboard, and the Digital Reactivity Meter [3], an in-house developed software to monitor the neutron flux and solve inverse kinetic equations to calculate the reactivity of the reactor online. The Digital Reactivity Meter and the digital acquisition software were running on a dedicated computer (“3.” in Figure 1 and Figure 3)

The exercise program made extensive use of shared online worksheets that were used simultaneously by multiple students with different roles. In the control room, the shared spreadsheets could be displayed on one of the personal computers (”2.” in Figure 1) or on the shared whiteboard (”4.” in Figure 1).

2.2 At the user side

At Uppsala university the students and their mentors were situated in a lecture hall specially designed for active learning (see Figure 8). The hall has five round tables, each with a large screen monitor, and the content of any of the monitors can also be mirrored on a white screen using a projector. A mobile conference system, connected to the speaker system of the lecture hall, was used for the students to interact with the instructors and the operator. Further more, each student had a laptop to facilitate their interaction with the data acquisition system, the Digital Reactivity Meter, the shared whiteboard and the shared spreadsheet.

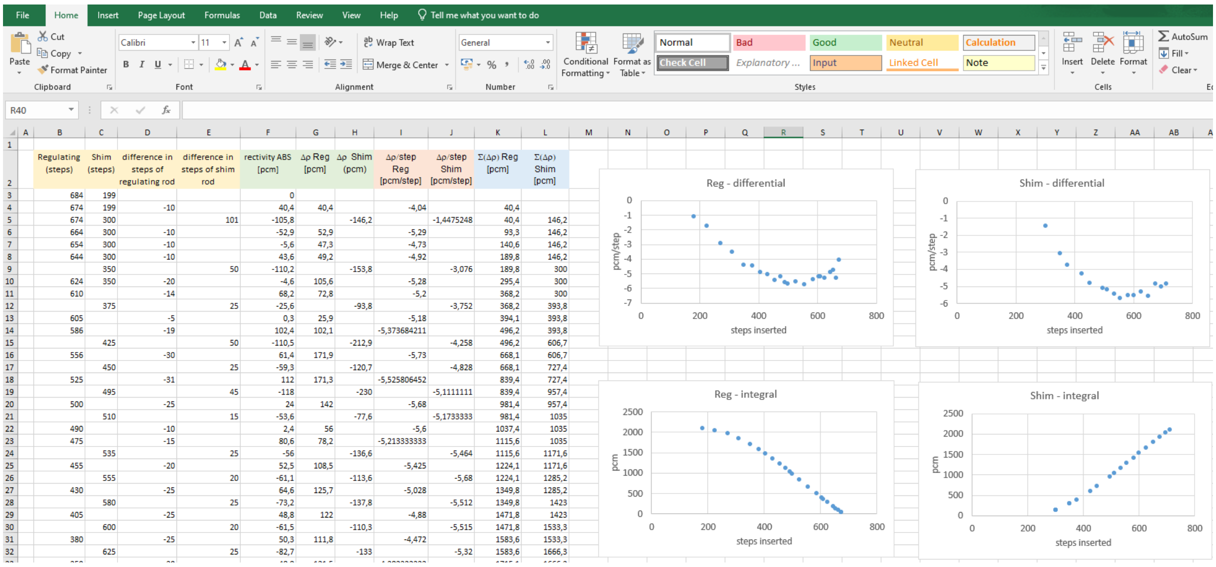


Figure 6: The shared spreadsheet edited by the students during the "rod swap" exercise. The students were entering the control rod positions and the respected reactivity changes each step and reconstructing the calibration curves seen on the right side of the screenshot.

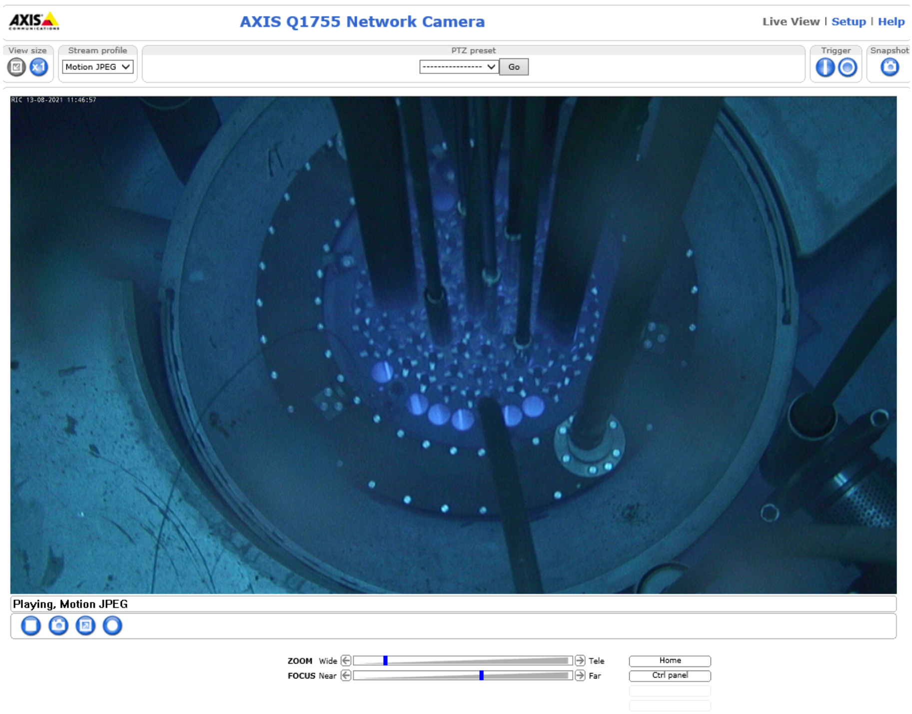


Figure 7: Cherenkov radiation is visible on the remote camera mounted above the reactor core. Students could view this camera at any time and use the zoom controls.

Figure 8: Picture of the active learning lecture hall at Uppsala during one of the exercises.

3 UPPSALA UNIVERSITY EXERCISE SCOPE

Jožef Stefan Institute offered a standard five-day course in reactor physics for undergraduate students from Uppsala University. The course started with an introductory session where students became familiar with the reactor. After a presentation of the facility and an overview of the course, the instructors took the students on a virtual tour of the reactor hall using portable cameras with zoom capability. The first exercise was the criticality approach, where students were asked to give step-by-step instructions to the operators on rod movements and estimate the current position at each step.

Students were assigned roles to encourage their active participation. One of the students entered the neutron count rates measured at each step into a shared online spreadsheet and estimated the current reactivity. Another student used the same spreadsheet to draw an automatic graph of the inverse count rate versus the inserted reactivity. One of the students drew the same chart on a shared whiteboard, one used the dome camera mounted in the control room to monitor the control rod positions, and another communicated with the reactor operator. Students were able to request that the neutron source be removed from the reactor core and observe the process and the reaction of the detectors using remote cameras. The second exercise dealt with the response of the reactor to step changes in reactivity. As with the previous exercise, students were able to give operating instructions to reactor operators and observe the reactor's response to reactivity changes using remote cameras. In addition to the rod positions and neutron flux monitors, students were able to use the remote camera mounted above the reactor core to observe Cherenkov radiation (visible in Figure 7) at higher powers and the remote desktop software TeamViewer to operate and read out the Digital Reactivity Meter (Figure 5).

During reactor operation, each student starts up the reactor, brings it to full power, and shuts it down under the supervision of a licensed operator. Since direct remote control of the reactor is not possible, students use videoconferencing software to give instructions to the operator and remote cameras to monitor the response of the reactor. The void reactivity coefficient is measured by blowing air bubbles into the reactor core and observing the effects on reactivity using the Digital Reactivity Meter [3]. In this exercise, the portable cameras were used extensively to show the details of the experimental setup on the reactor platform. The last two exercises were measurements of the value of control rods, where students measured and reconstructed calibration curves using either the rod swap method or the rod-in method, and a measurement of the temperature-reactivity coefficient, where students instructed operators to

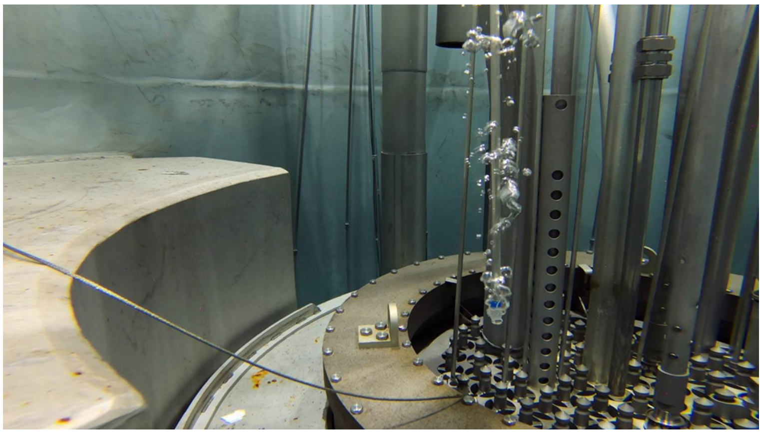


Figure 9: The picture was taken under water with an action camera and is demonstrating how the ”void reactivity coefficent” exercise is performed. The operators insert an empty tube in the reactor core and blow air bubbles. During the experiments the students can track reactivity changes on the Digital Reactivity Meter.

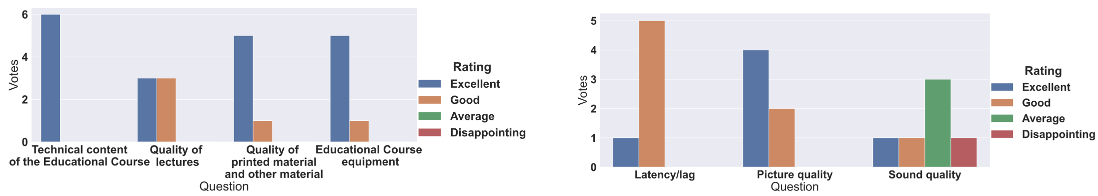
move the control rods over the point of active heat and recorded the change in fuel temperature and reactivity at each step. The shared spreadsheet created by students during the rod swap method is provided in Figure 6.

3.1 FEEDBACK INFORMATION

Feedback was obtained anonymously from students and their mentors via an online form. Instructors asked both choice questions and open-ended questions about the content of the exercises, staff performance, and technical execution of the remote exercises. Figure 10a shows a summary of the results related to the ”Technical content of the Educational Course” the ”Quality of lectures,” the ”Quality of printed material and other material” and the ”Educational Course equipment” all of which were rated as ’Excellent’ or ’Good’. The responses to the open-ended questions were also mostly positive. Participants praised the content of the lectures and the opportunity to actively participate in the exercise and experience the role of the nuclear reactor operator. Some participants noted that students were sometimes not given enough time to find the answers to the questions and stated that students sometimes felt lost, especially at the beginning of the exercise. One of the participants recommended that the lecturer should give clear, practical instructions before starting the experiments or give students more time to solve the task themselves. The most frequently mentioned weakness was the quality of the audio transmission. Several participants complained that they sometimes could not hear the lecturer when they moved away from the microphone.

The audio difficulties were also reflected in the ratings of the remote session in Figure 10b, where image quality and latency were rated as ’Excellent’ or ’Good’ by all participants, while audio quality was also rated ’Average’ or ’Disappointing’. Corrective action was later taken and the demonstrators wore wireless headsets.

Participants agreed that such a course should be routinely organized and that other nuclear staff and students could benefit from similar exercises. Five participants described the organization and administration of the training course as ”Excellent” and one as ”Good” When asked about the staff and their willingness to help solve their problems, again five participants responded ”Excellent” and one ”Good”.



(a) Survey results concerning content and quality of the lectures.

(b) Survey results about the remote session.

Figure 10: Results from the anonymous survey. A total of six participants took part in the survey.

4 CONCLUSION

The international students were able to complete all the scheduled exercises even during periods of restricted travel. The authors of this paper believe this is extremely important, as live exercises give students a different insight into reactor physics than theoretical lectures. The remote exercises even have some advantages over face-to-face exercises, especially lower costs as no travel is required, and the schedule can be more flexible. Despite the advantages of remote exercises, lecturers believe that they should only be used as a fallback option when face-to-face exercises are not possible. Lecturers observed that students asked fewer questions and did not participate as actively in distance exercises as they did in face-to-face exercises. Unless foreign students are prevented from traveling to Slovenia or the country is completely sealed off, it is often possible to organize face-to-face exercises in smaller groups despite pandemic-related restrictions. This was demonstrated in 2021, when Jožef Stefan Institute safely organized face-to-face exercises for students at the Faculty of Mathematics and Physics from University of Ljubljana by maintaining a safe distance between participants and by using personal protective equipment.

ACKNOWLEDGMENTS

Special thanks go to the staff of the Reactor Infrastructure Center of Jožef Stefan Institute for adapting to the new exercise format and installing the necessary equipment, and to the students and professors from Uppsala University for working closely with the staff from Jožef Stefan Institute and making the exercises possible.

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