

Delivering the Nuclear Promise Top Innovative Practice



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Virtual Reality Polar Crane Simulator 2023 Top Innovative Practice Winner¹

Summary

The Tennessee Valley Authority (TVA), in partnership with Industrial Training International (ITI)², addressed a major challenge in reactor maintenance concerning training for polar crane operation. With polar cranes being nearly unique to the nuclear industry,³ polar crane operators had few options for practicing their skills. Crane operators could practice a crane operation scenario only during actual lifts. This presented undesirable risks to personnel and plant equipment. To reduce these risks, in 2021 TVA collaborated with ITI to develop a virtual reproduction of the Watts Bar Unit 2 containment area in which the polar crane is used. In this virtual environment, operators can practice specific scenarios including lifts of the reactor head, gates, missile shields, upper and lower internals, core barrel, and reactor coolant pump motors, with zero risk to themselves or vital plant equipment. TVA also found the virtual environment is useful for helping members of the rigging crew to visualize load paths and optimal placement of personnel. The ITI Virtual Reality (VR) Polar Crane Simulator consists of a laptop paired with VR goggles and interchangeable control pods. The control pods simulate the actual controls of the crane that will be used. The simulator can be packed into two Pelican™ cases and is easily transportable between Sequoyah Nuclear Plant and Watts Bar Nuclear Plant.

Innovation

Due to ambient conditions in containment (e.g., radiation, heat and humidity, congested floor areas, the number and safety significance of equipment) and limited availability of heavy components to be lifted in containment, crane operators are not able to practice polar crane lifts with the installed polar crane. Typical hands-on training allows the operator to perform movement only of light loads around containment to become familiar with the basic motions of a polar crane. Therefore, operators commonly train using a rectilinear overhead crane that is in a safer, more accessible location. However, this type of crane cannot simulate the unique motions and challenges of polar crane operations in the containment. Working together, TVA and ITI used the existing technologies of Light Detection and Ranging (LiDAR) mapping, VR, and video game design to build a tool to allow operators to practice rarely used unique crane lifts in a virtual environment. The value of this tool was recognized by assessors from the World Association of Nuclear Operators (WANO), who rated its use as a strength at Watts Bar and said it was a contributing factor to the plant's exemplary rating.

¹ Winning entries of from NEI's Top Innovative Practices (TIP) awards are republished as DNP Efficiency Opportunities to ensure the broadest possible dissemination of these operating plant innovations.

² Industrial Training International, information available at <https://www.iti.com>.

³ In the United States, pressurized water reactors have a circular containment design and employ a polar crane to move heavy components within containment.

Background

Refueling outages of pressurized water reactors (PWRs) normally occur only every 18 months or more. During such major shutdowns, the reactor is disassembled. Without a simulator, the complex and high-precision lifts needed for reactor disassembly could not be learned and practiced except by performing the actual lift. TVA sought a way to practice such lifts more often than every 18 months and without risk to personnel or vital equipment. Thus in 2021 TVA collaborated with ITI to develop a polar crane virtual environment and lift scenarios for their Virtual Reality Crane Operator Simulator.

TVA utilized LiDAR technology to scan the containment of Watts Bar Unit 2. This scan was used to build a virtual environment identical to the containment in which the polar crane is used. This virtual environment is applicable to both units at Sequoyah and Watts Bar.⁴ From drawings, pictures, and videos of the real lifts, each major lift that occurs in a refueling outage was built into separate scenarios. These scenarios include lifts of the reactor head, gates, missile shields, upper and lower internals, core barrel, and reactor coolant pump motors. Using virtual reality goggles, crane operators can develop their skills in a simulated environment.

In the past, the only way to practice polar crane operation was for the operator to begin lifting loads. Now, TVA's new VR simulator allows operators to practice and improve without endangering themselves, others, or plant equipment. This allows an operator to practice a specific lift immediately before performing the real lift. Other benefits include being able to perform multiple lift scenarios with no setup time in between and being able to practice rarely used skills needed for difficult lifts as many times as it takes to become proficient. Rigging crews also benefit from the tool because it allows them to visualize the load path and where crew members should be stationed to safely guide a load. It also supports TVA's As Low As Reasonably Achievable (ALARA) radiation protection goals by keeping the operators, signal personnel, and riggers away from radiation and contamination hazards.

The ITI VR Polar Crane Simulator consists of a laptop paired with VR goggles, and interchangeable control pods. The control pods simulate the actual controls of the crane that will be used. The simulator can be packed into two Pelican™ cases and is easily transportable between Sequoyah and Watts Bar.

Figure 1 shows the ITI VR Polar Crane Simulator desktop setup. Figure 2 is a demonstration of the simulator for the public during Watts Bar's Community Day. Figure 3 is the view from the floor while lifting a reactor head. Figure 4 is a view from the cab while lifting a reactor head.

Safety

Traditional polar crane operator training methods require the operator to be physically in a crane cab, lifting an actual load in the actual environment where the real lifts will occur. In a production environment, this puts the rigging crews and plant equipment in potentially hazardous conditions. If the load is lost or contacts plant equipment, a training scenario can quickly become a real, unsafe situation. The ITI VR Polar Crane Simulator enables training to take place in a virtual environment. This removes any danger to personnel and plant equipment.

The VR tool also supports the company's ALARA radiation protection goals. By moving the training environment from the plant to a simulated one, the radiation exposure to the operator and the rigging crew from working in containment can be avoided. TVA found that use of the simulator reduced dose to plant personnel by approximately 50 millirem per outage. Use of the simulator also allows the rigging crews to see where the safest locations will be during a lift and allows them to get a better visual of the safest way to distribute the crew.

⁴ Sequoyah and Watts Bar are sister plants with Westinghouse four-loop nuclear steam supply system designs with ice condenser containments.

Cost Savings

Before the simulator was available, crane operator training required the operator to be placed in the actual crane used for a lift. However little time could be allotted to train or practice in the polar crane because of the environmental hazards (e.g., radiation, heat and humidity) and limited availability of liftable components. In the real polar crane environment, lift scenarios cannot be practiced ahead of time because the equipment is inaccessible. This lack of training could lead to mistakes during actual lifts that could affect safety or schedules during outages.

With the ITI VR Polar Crane Simulator, an operator can practice a scenario as many times as necessary to gain proficiency. At Watts Bar, during the Unit 1 refueling outage in September 2018, crane down time (such as automatic trips) arising from crane operator performance issues was approximately 24 hours. Since the crane simulators were installed, operators must spend a minimum of four hours each on a crane simulator. Since then, down time due to crane operator performance issues during outages decreased to zero hours. This represents a potential of \$1.2 million in avoided costs in just a single outage. These savings will multiply during subsequent outages across the TVA fleet.

Productivity/Efficiency

Without the ability to perform and practice actual lifts outside of a refueling outage, a polar crane operator might enter an outage without having performed these lifts since the last outage, or never having performed these lifts at all. With the polar crane simulator, operators and rigging crews can practice these lifts as many times as necessary to increase their proficiency, safety and efficiency. This is not only due to learning the best path for each load, but also due to familiarity with the unique motions of a crane that operates in polar coordinates.

Transferability

The ITI VR Polar Crane Simulator has been implemented at Watts Bar and Sequoyah. This technology is available for other pressurized water reactors with ice condensers. While the virtual environment developed for the TVA units would differ from that of other PWR containment designs, the VR crane simulator could be used by plants of any design to familiarize operators with polar crane movements. TVA has demonstrated this technology to other nearby utilities and at the local trade halls. The halls that supply TVA with operators are considering purchasing this technology to better prepare their operators for working with TVA. It would also be possible for other plants to provide drawings or LiDAR scans of their own containment to develop a virtual environment that better matches their containment designs.

Team Members

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Additional Information

Figure 1: ITI VR Crane Simulator desktop setup.



Figure 2: Demonstration of the Simulator during Watts Bar's Community Day



Figure 3: View from the floor while lifting a reactor head



Figure 4: View from the cab while lifting a reactor head

