REMOTE FEEDER REMOVAL FOR CANDU 6 AT HYDRO-QUÉBEC

Eric LAVOIE, Alain DROLET, Pierre GAUTHIER

ABSTRACT*: As a baseline for all CANDU 6 refurbishment project, AECL has retained a manual removal method. However, the higher radiation levels at the Gentilly 2 power plant, and the relative uncertainty of the heat transfer system (HTS) decontamination outcome, has pushed HQ's higher management to finance a feasibility study analyzing a novel approach for the feeder removal. For the last 2 years, Hydro-Québec has been working on an alternative way to remove feeder in preparation for the refurbishment of its power plant. The process would use Teleoperated Master-Slave Mechanical Arms to remotely perform the entire feeder removal task thus reducing the radiation exposure and increasing the overall safety of the worker. This paper will present an overview of the work executed in this study, putting emphasis on the actual Remote Feeder Removal (RFR) scenario, its principal tasks and the tooling developed to achieve this. This work was executed through a close relationship between the Hydro-Québec Research Center (IREQ) and Gentilly-2 pre-refurbishment project teams.*
Keywords: Feeder Removal, Teleoperation, Robotics, Refurbishment

I. INTRODUCTION

Candu 6 Retube Projects include feeder pipe removal. The scope of the feeder replacement has evolved from the replacement of the lower feeder section only (pre-2004) to that of the complete lower and upper feeder pipework, all the way up to the headers. AECL's selected approach has always been based on a manual removal method, despite the significant increase in the removal scope. The perceived high risk level associated with the employment of such a method on the Gentilly-2 (G2) reactor justified the exploration of an alternative method that would limit human intervention. A Hydro-Québec (HQ) work group, including experienced G2 reactor project staff and IREQ robotic specialists, was formed to assess the feasibility of a remote feeder removal method. The work done by Hydro-Québec clearly shows that not only is a remote removal method feasible, but it also has the potential to significantly reduce the dose and duration associated with this activity.

A. JUSTIFICATION FOR A REMOTE REMOVAL METHOD

The radiological fields in the vault area of the Gentilly-2 reactor are high. Typical gamma readings range from 50 to 80 mRem/h, as measured on the floor at the room center, up to 1000-1200 mRem/h, as measured a few inches away from the upper feeder pipework. Partial heat transport system (HTS) chemical decontamination is scheduled to be performed prior to feeder removal. A decontamination factor of ten is sought after to bring the level of gamma fields in the G2 reactor vault on par with that of the Lepreau reactor. According to available industry information, past Candu reactor primary side decontamination has achieved no better than a 5 average decontamination factor. The collective dose associated with manual feeder removal was estimated by AECL at approximately 450 person-Rem for Lepreau. Given the uncertainty inherent to post HTS decontamination, a remote removal method is a contingency plan that would allow the refurbishment activities to proceed according to schedule if the required decontamination factor is not achieved.

Personnel safety during radioactive feeder pipe handling, boilermaker availability and the perceived risk of working in a radiological environment all point towards a remote removal method. Additional advantages to limiting human intervention are improved performance and efficiency due to reduced human error.

B. STUDY SCOPE

The global feeder pipe removal activity can be divided into three distinctive blocks:

1. Feeder insulation cabinet tear down,
2. Cutting of feeders, cutting of associated hardware such as tubing and hangers, extraction of cut sections from the pipework and finally, delivery of these components onto the vault floor, and
3. Subsequent re-cutting of feeder sections, packaging in waste boxes and transferring these waste boxes outside the reactor building.

The feasibility study undertaken by Hydro-Québec and presented herein addresses only item #2. The decision to focus on the cutting and handling of the pipes was made during the initial phase of the feasibility study. It was clear in the project team members' mind that cutting, extracting and transferring long and intricate pipe sections to the vault floor for further processing would be the most challenging aspect of the remote method and yield the greatest potential in dose and time saving.

The feasibility study was done in two phases:

Phase 1:

- Conceive a practical remote method through the analysis of various pipe cutting and handling concepts,
- Build and test a cutting head prototype tool,
- Test various handling concepts and
- Demonstrate feasibility.

Phase 2

- Address cutting and removing of the tubing and hangers,
- Further test and select a pipe handling concept,
- Improve the cutting head prototype versatility
- Elaborate the system's architecture and control and
- Demonstrate feasibility on the feeders which are most difficult to access, cut and extract.

II. OBJECTIVES & DESIGN CRITERIA FOR THE REMOTE APPROACH

The main objective in the development of a remote removal method is to establish the right balance between three competing factors:

- Collective radiological exposure
- Duration and impact on the retube critical path
- Tooling and process development cost

The duration of the feeder pipe removal must be as short as possible, while minimizing the dose and tooling development cost. The investment required for the proof of concept, the design, the fabrication, and the integration of all the components, as well as the training of the operators, must remain at an acceptable level in relation to the productivity gain and dose reduction. In short, the ALARA principle should prevail.

The total duration of the removal was evaluated through full scale mock-up trials. The estimate assumes the use of two complete and fully independent systems operating in parallel, one at each reactor face. However, the analysis shows that in certain work areas, it would be possible to use two systems in parallel on the same reactor face, thus further reducing the duration. In as much as it is possible, the removal process and tooling design choices have been compatible with the use of two systems working in parallel on the same reactor face. There is nevertheless an important concern to consider with this possibility: The coordination of two systems simultaneously in operation on one reactor face entails a level of complexity that could risk offsetting the anticipated gain in productivity.

The criteria governing system design and solution selection are as follow listed in order of importance:

1. Minimize human intervention in the proximity of the feeder pipe.
2. Collect the feeder pipe cutting debris directly at the source.
3. Control the spread of airborne contamination and debris while manipulating the cut sections.
4. Use the fuelling machine bridge as a positioning and work platform for the various systems at the face of the reactor and when possible use the shielded platform.
5. Encourage the assembly and the commissioning of systems in the Fuel Machine (F/M) maintenance area before their transfer to the reactor face.
6. Maintain the reactor face floor area free of stationary equipment and minimize the size of such equipment. These measures aim to facilitate the deployment of an autonomous motorized work platform if human interventions are required.
7. Keep the variety of equipment, systems and tools to a minimum.
8. Employ only proven technologies.
9. Favor simplicity and robustness in the systems.

A. IDENTIFICATION AND DESCRIPTION OF THE WORK ZONES

Work zones and cutting planes were established according to the piping geometry and the path of access to each pipe. It is required to stagger the cuts in most zones given the geometry of the pipework, as well as to allow the repetitive insertion of the cutting head in the pipework for sequential feeder removal. Initially, there were five different work zones. As the task analysis and simulation work progressed, the benefit of removing individual upper feeders as a single piece became apparent. Lab trials on mock-ups led to the retention of four work zones instead of five. These zones are:

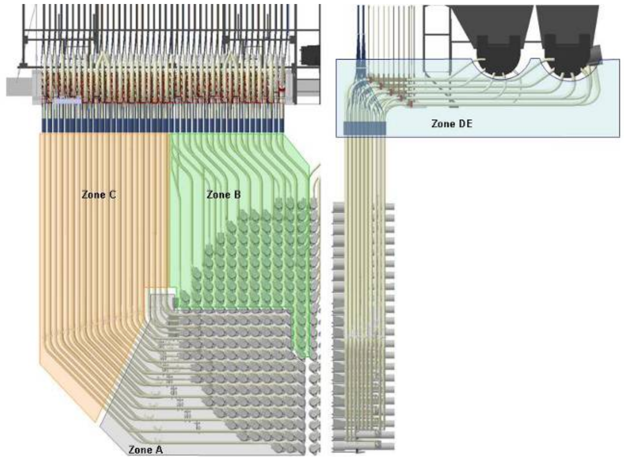

Figure 1:Workzones

- Zone A: The lower half of the reactor face which includes the horizontal feeder pipes and one of the two 45 degree elbows. The Grayloc fitting is also included in this zone.
- Zone B: The upper half of the reactor face. This zone extends up to the bottom of the permanent freeze jacket. The Grayloc fitting is also included in this zone.
- Zone C: The vertical feeders located to the left and right of the reactor core perimeter. This zone includes the second of the two 45 degree elbows and extends up to the bottom of the permanent freeze jacket.
- Zone DE: Usually called "the upper feeders". This zone includes a short vertical section, the freezing jacket, the 90 degree bend above the freezing jacket and a horizontal section up to the cutting position near the reactor headers

B. SHIELDED PLATFORM

In 1995, Gentilly-2 had General Electric (GE) design and fabricate a shielded platform for work at the face of the reactor and feeder inspection. Since then, this custom built platform has been used extensively and has proven so advantageous that a second platform was recently acquired to reduce the duration of the outage's critical path. The platforms are under slung on the fuel machine bridge and locally driven in the X and Z direction while relying on F/M bridge drives for elevation. These "G2-specific" platforms are key components in the Remote Feeder Removal (RFR) method and allow for limited human intervention while respecting the ALARA principle and minimizing development cost.

C. TOOLING

As stated above, it is the goal of this project to use proven technologies. In some cases, it was necessary to develop specific tooling to better achieve the task but all the prototype tools actually rely on proven technologies.

1) TELEOPERATED ROBOTIC ARM

The robotic manipulators used in the feasibility study are commercially available force feedback teleoperated arm from Kraft Telerobotics. In the study, both the Predator and the Grips models have been used. These arms are teleoperated, meaning that the operator does not need to be directly in the work zone but rather farther away, safe from radiation or possible accident. In most case, and this was one of the goals of the demonstration, the operator was using indirect vision (i.e. by means of camera and screen) A force feedback feature allow the operator to "feel" some the weight of the load, letting him decide what course of action to take. Though not yet implemented, it is part of the project to add some pre-programmed functions to these manipulators. This would permit to arm to execute some specific routine tasks with less input from the operator, thus easing its workload.

2) FEEDER PIPE CUTTING HEAD

The feeder pipe cutting head is the most important prototype tool developed during this project. It latches on to the pipe segment to be removed and relies on a rotary blade to perform the cut. The blade is entirely enclosed when the cutting head is attached to a feeder and steel chips produced during the cut are collected by a vacuum system. Feed and blade rotation speeds are controlled to optimize performance and durability. The prototype cutting head is designed to cut 1.5 to 3.5-inch feeders on straight sections and on 15-inch radius bends. Experiments show adequate blade performance for a minimum of 100 cuts of feeders of various sizes with the duration of the cuts varying from 15 to 25 seconds depending on the pipe size. The cutting head features a mechanical quick mounting adaptor and is handled by a tele-operated manipulator arm.

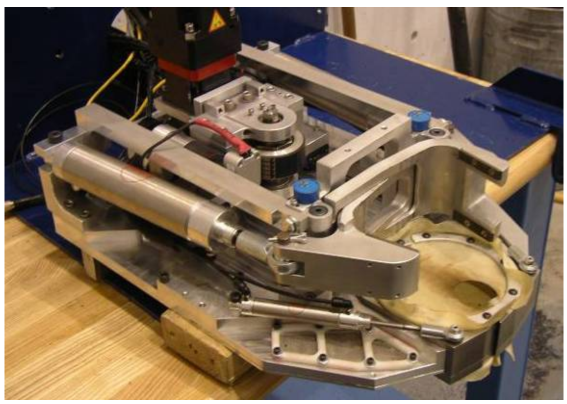

Figure 2 Feeder Pipe Cutting Head

3) TUBING CUTTER AND SUPPORT ARM

The tubing cutter prototype was derived from a small shear cutter typically used by a rescue team to extract victims from car crashes. It is used to cut away DN and RTD tubing in the insulation cabinet. The tubing removal approach requires the cutter to be supported by a dedicated arm with a 2 degree of freedom wrist and 2 sliding mechanism.

Figure 3: Tubing cutter

4) PIPE HANGER CUTTERS

Similar to the tubing cutter, the pipe hanger cutter, as its name says, is a modified version of this last tool to remove the seismic hanger holding the feeder in the upper feeder section (Zone DE). The shear cutter blade holder was customized in order to allow for the insertion of the blades between horizontal upper feeder rows to cut the hanger side bars. The cutting action relies on hydraulic power and an air-to-hydraulic booster pack is used to deliver 10,000 Psi of pressure to the cutter cylinder. As for the prototype cutting head, the hanger cutter also features a mechanical quick mounting adaptor and is handled by a tele-operated manipulator arm.

Figure 4: Pipe Hanger Cutter

5) FEEDER HANDLING ARM

The prototype feeder handling arm was designed to grab an upper feeder, hold it during the cutting process and bring it to the back of the F/M bridge where a "catch and hold" system, positioned with an elevating device or fork lift located on the vault floor, is ready to receive the cut feeder.

Figure 5: Feeder Handling Arm

The prototype handling arm has three main components: a claw, a wrist and an articulated boom. The claw was designed to hold the feeder whether or not the feeder is at its center of gravity. The claw operates hydraulically and is fail safe. Clamping on the feeder requires a compensation mechanism to allow the clamp to bite straight into the feeder without imposing any stress on the header pull-out. This is achieved by the wrist which uses a hydraulically-actuated roll and yaw axis which are set free during the clamping action and then locked. The system can also preload the feeder in order to balance the load and minimize movement of the feeder sections upon separation. The boom is made up of two hydraulically-actuated segments which are optimized to reach every feeder when mounted on top of the F/M bridge. It has a 600 pounds weight capacity, a 12 foot reach and a 270 degree rotational capacity. The manipulator arm has also been designed to accommodate an offset load.

6) OTHER TOOLS

Grayloc quick disconnect tool requirements were briefly analyzed during the study. The design of a special hexagonal key for the locking wire and plate, limited tests on Grayloc fittings and the simulation of a low profile, high torque, hydraulic-powered wrench showed good potential for the development of a rapid manual Grayloc disconnect method. A different approach that would be more coherent with the remote removal process would be to use AECL's Grayloc bolt shearing technology. Another important aspect that was not analyzed in the course of the study is the closure plug removal system.

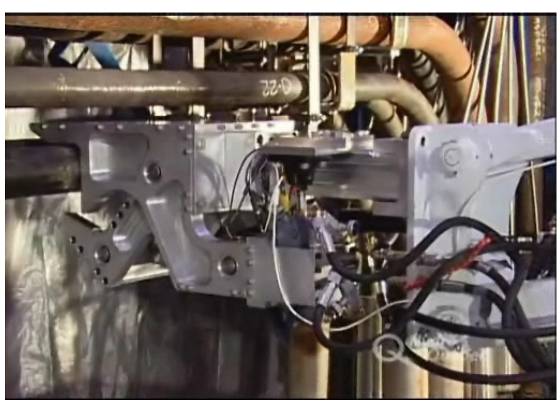

Figure 6: Feeder Handling Gripper

III. VIRTUAL SIMULATION

Throughout the entire project, virtual simulation of the feeder removal method was essential in determining the best solution. The simulation was run on the CAD software CATIA using a complete virtual mock-up of the Gentilly plant, developed by HQ over the years to aid in the development of various robotic systems.

During the first phase of the project, simulation was used to conceive new ideas or concepts and then to test them in the virtual environment since the full size physical mock-ups were not yet available. For example, simulation was used to determine the workspace required by the various tools and to optimize the paths and sequences by which to remove the necessary objects from the reactor face. Virtual simulation videos also serve as an excellent promotional tool for the project and allow its progress to be visualized by the various contributors.

In the subsequent phase, virtual simulation was used in conjunction with tests on the physical mock-up to prove and demonstrate various concepts and to further develop others when space, time or materials were unavailable. The simulation was always created to duplicate reality as closely as possible. In other words,, no steps were skipped and no short cuts were taken. In most cases, the models used to create the simulation were identical to those used for fabrication, thus allowing the team to be confident that they would experience similar reactions in practice to those simulated.

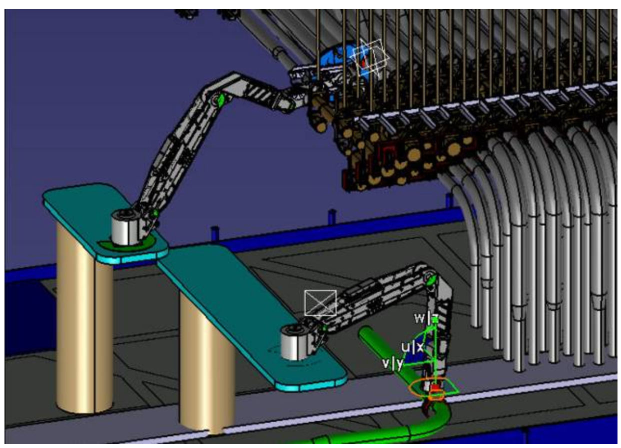

Figure 7: Virtual simulation in the upper feeders

Finally, the simulation was used to create a complete video showing all aspects of the feeder removal method, including the sequence of operations, and to complement the lab demonstrations. The video is available from the authors.

IV. REMOTE REMOVAL PROCESS

A. GENERAL PRE-REQUISITES

The general pre-requisites are the following:

- Reactor is defuelled,
- HTS piping has been light water decontaminated,
- Fuelling machine has latched to each individual fuel channel for draining

- Closure plugs have been removed and a temporary plug has been manually installed on, or in, each of the end fittings if a HTS vacuum drying step is required prior to feeder removal (drying is part of the current Retube plan).

Note that the insulation cabinet is dismantled in two different steps to reduce dose and create a physical protective barrier to support parallel tasks on lower feeders and on DN and RTD tubing.

1) PRE-REQUISITES FOR FEEDER REMOVAL IN ZONES A AND B

The insulation cabinet must be partially removed. Flexible insulation panels with mounting collars located around the end fittings, rigid insulation panels together with the external framing and supporting structures as well as header pressure measurement tubing lines and support trays need all to be removed first.

The eye rod or chain link cantilever supports are cut using modified industrial hydraulic cutters. The tool is mounted on a pole in order to reach inside the pipework and is manipulated by workers from the shielded platform. An identical approach is used to cut and retrieve the lower spacer block links, as well as the upper spacer block links for rows L to Q. The remaining links cannot be reached from the shielded platform but will be manually removed once zone A, zone B and partial zone C feeders are taken out.

B. TRAPPING FEEDER

If AECL's Grayloc shear tool is used, manual removal of 35 feeders is required to allow access to certain feeders before fully remote operation on the remaining Grayloc can begin. In this case, removal of the "trapping feeders" becomes a pre-requisite. An under slung positioning trolley with a tele-operated manipulator arm and feeder cutting head is required on each side of a shielded platform. These systems are installed and commissioned on the maintenance bay fuel machine bridge. Another option is to use a combination of custom and commercial l hand and power tools to manually disconnect all 760 Grayloc connections from the shielded platforms. In this case, only the shielded platforms must be installed and removal of the trapping feeders would not be a pre-requisite.

C. REMOVING CLOSURE PLUG AND DISCONNECTING GRAYLOC

Removing and handling the closure plug is performed remotely by a hydraulic-powered plug removal system, which is mounted on an under slung positioning trolley. The removal system latches onto each end fitting and extracts the closure plug. A collection bin featuring a special chute is positioned at the right elevation by a fork lift on the vault floor. The removal system drops each closure plug into the bin.

The Grayloc shearing activity begins once the removal of the closure plug has been completed. The hydraulic shear tool (EACL) is mounted on an under slung trolley and is remotely operated. Tool mounting and operation are similar to the closure plug removal. The shielded platform allows the workers to safely retrieve the screws and seal rings, install plugs on the end fitting side port and in the feeder hub once all Grayloc are sheared.

D. ZONE A FEEDER REMOVAL

All removal steps are performed remotely once the system and positioning trolleys are installed and commissioned on the maintenance bay F/M bridge. Two independent under slung trolleys are required. One provides a tele-operated manipulator arm equipped with the cutting head, and the other, a second tele-operated arm on which a special gripper is mounted. Removal begins on row K feeders. Once transferred to the vault and positioned at the right elevation with the F/M bridge, the cutting head latches onto the first accessible feeder and cuts the pipe. The catch tray must have been previously positioned in such a way that the cut feeder need only be slid along the end fitting top surface before it ends up in the tray. The tele-operated manipulator arm with the gripper helps with the sliding motion, acting on the close radius elbow located closest to the Grayloc. Both manipulators work in tandem to position the pipe in the catch tray in order to make room for the next section of pipe.

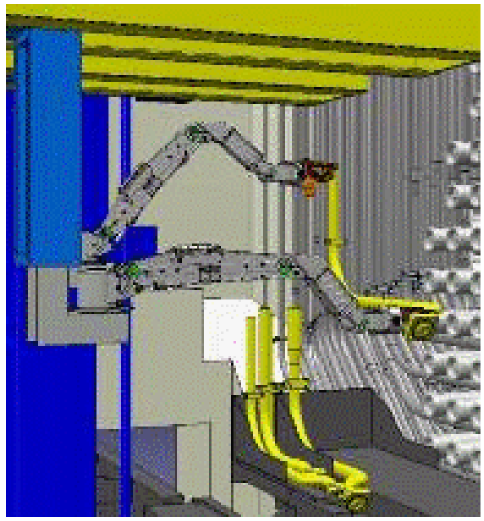

Figure 8: Zone A Feeder Removal

This operation is repeated until the catch tray is full at which point, it is lowered to the floor with the fork lift and replaced by an empty catch tray while the full tray is taken care of by a waste handling crew.

E. ZONE B FEEDER REMOVAL

In this zone, a single under slung positioning trolley carries the tele-operated manipulator for the cutting head as well as the feeder handling manipulator. Both systems must work in close proximity as the cut plane and the gripping location are within a couple feet of each other along the pipe to be removed. Installation and commissioning are carried out in the F/M maintenance bay. Precise vault bridge elevation and lateral trolley displacement are required to initially position the cutting head on top of the core reactor center. The removal work begins on row B feeders. The feeder handling manipulator arm grips the pipe as close as possible to the row A end fittings in order for the center of gravity to be below the gripper. The cutting head latches onto the pipe and performs the cut. Both robotic arms work in tandem to extract the cut feeders from the pipework. Once the extraction is complete, the gripper manipulator arm lowers the pipe enough to clear the F/M bridge structure. Rotation of the manipulator along its vertical axis allows the cut pipes to be transferred to a lowering system.

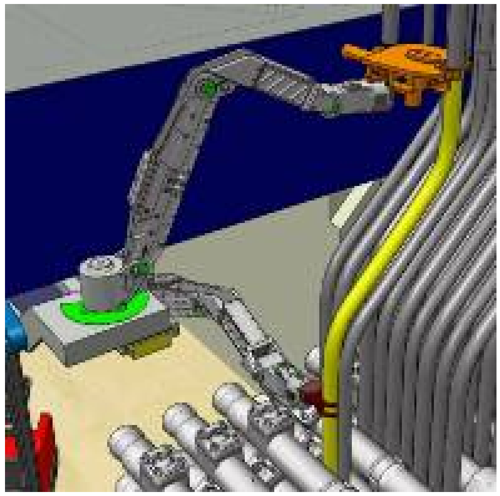

Figure 9: Zone B Feeder Removal

F. ZONE C FEEDER REMOVAL

The major difficulty in this work zone is the position of the outmost vertical row feeders with respect to the F/M bridge envelope. The cutting head and the handling gripper are required to reach feeders many feet away from the end of the bridge rolling rails. The bridge's lateral columns also impede certain manipulator motions and somewhat limit its freedom. The solution is to implement a cantilever feature on the positioning trolley. The cutting and removal work is performed similarly to that of zone B except that the gripping position is not as constrained.

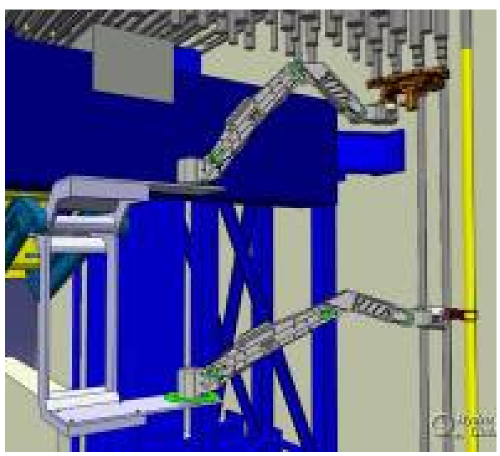

Figure 10: Zone C Feeder Removal

G. DELEAYED NEUTRON (DN), RESISTIVE THERMAL DETECTOR (RTD) & NITROGEN TUBING REMOVAL

The DN and RTD tubing are also removed using a remote system. The tube cutting work is performed from the DN catwalk during the lower feeder removal (zones A, B and C). Tubing penetration panels are removed to allow the cutter access, but the insulation cabinet roof panels are kept in place thereby creating a physical barrier for the waste handling workers on the vault floor. All tubing need to be cut into small segments in order to free up the cutter insertion path up to the RTD terminal mounting block.

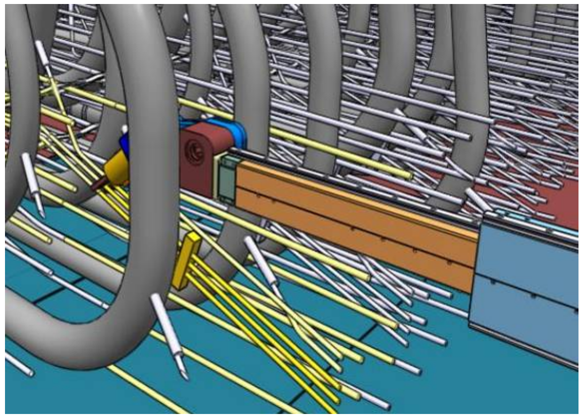

Figure 11: DN and RTD removal

The system is composed of three components for cutter positioning and insertion between the rows of upper feeders: a floor mounted linear track, a vertical mast and a horizontal boom. The general method consists of cutting its way into the crowded tubing space between each of the feeder rows in sequence. There are 22 paths for tool insertion for each outlet header. The sections of DN tubing are first cut into small segments that fall on top of the insulation layer. This operation is repeated along six or seven insertion paths. The tubing segments are then manually collected and a pan is installed to collect the remaining DN and RTD tubing segments. Insertion of the cutter can resume and can progress further, cutting the RTD tubes and retaining steel bands in its path. The RTD's mounting block and a one-foot tubing segment are left on each feeder. Once the mast has reached the floor track limit, manual intervention is required to move the system along the catwalk, collect the cut tubing segments and repositioned the pan.

H. ZONE DE FEEDER REMOVAL

The removal of the insulation cabinet panels, cabinet support structure and header axial restrain inspection platform, and the cutting of the DN and RTD tubing are pre-requisites for feeder removal in this zone.

Three independent systems are required to address the various removal tasks in this zone: a feeder cutting system, an extraction and handling system and a hanger cutting system. The extraction and handling system has its own dedicated trolley, while the two others share a second trolley. Linear tracks allowing movement from the front to the back of the F/M bridge are integrated into each trolley. One set of linear tracks spanning the entire width of the F/M bridge is also required on top of the bridge. One rail sits on the front end steel beam, and the other on the back end steel beam. All three systems are pre-commissioned in the maintenance bay and delivered on the F/M bridge with a fork lift. Removal work begins at reactor center line. The handling arm claw is driven into position, attached to a feeder and locked in position. The cutting head latches onto the feeder to be cut, while the hydraulic hanger cutter blades are inserted into the hanger to cut the first lateral bar supporting the yoke. Once the first hanger side bar is cut, the cutter immediately moves on to the second bar in order to liberate the pipe. Nitrogen tubing is bound in pairs with a steel wire that blocks the extraction path. These wires are cut with the hanger cutter. The hanger cutting system retracts once the feeder is free of all restrains. The yoke is left on the pipe and the remaining hanger portion is raised and locked in position by a worker in the room above (room 501). The cutting head cuts feeder and then retracts to facilitate the extraction. Extraction begins with a vertical displacement to disengage the nitrogen tubing from the freeze jacket. The next movement is to free the feeders from the whole nitrogen tubing arrangement. Once clear of the nitrogen tubing, the manipulator arm moves along to a position which allows the pipe to be transferred to the "catch and hold" system located at the back end of the bridge. This cycle is repeated until an entire row has been removed before the feeders are lowered to the vault floor.

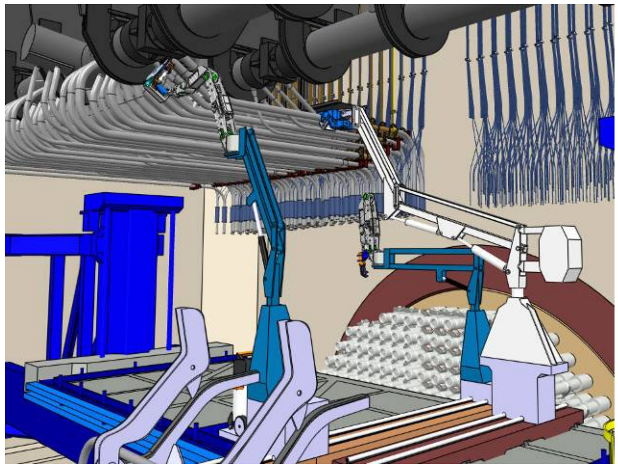

Figure 12: Zone DE Feeder Removal

V. PROCESS CONTROL

Commercially available telemanipulator arms were used throughout this project to manipulate various tools and to handle cut feeders. The lightness and dexterity of these manipulators meet the requirements for ease of deployment and tool maneuverability in a physically constraining environment. Force feedback is also a key feature inherent to telemanipulation, and it permits the operator to rapidly adjust to the environment, especially when this environment is not exactly as planned on the drawings. Considering the Cartesian nature of the pipework, the removal process would benefit from a mixed-mode type of control: the cutting head and cut feeder handling gripper would be positioned in the work environment through a sequence of pre-programmed movements (trolley and manipulator arm), while the precise operations required to seize the pipe and to engage the cutting head would be performed entirely through teleoperation. Similarly, the extraction of the cut feeder from the pipework would rely fully on teleoperation, while the handling and transfer of the cut feeder to the lowering system would employ pre-programmed movements.

Regarding the control center, it would be necessary to centralize the tool/system control panel and coordinate the work from a single control station for each operation at the reactor face. Each of the mechanical systems employed in the same work zone must be controlled by an independent operator. A system typically comprises a positioning trolley, ensuring linear movements along the Z axis (North-South direction), along the Y axis (East-West direction) and also at times along the X axis, and a manipulator, whose various degrees of freedom are operated by a master arm or through a sequence of pre-programmed movements. The operator should rely on cameras, which have been strategically positioned, to accomplish his tasks. The positioning and operation of the feeder pipe lowering system on the vault floor should be performed using a local control system (pendant) under trade personnel supervision.

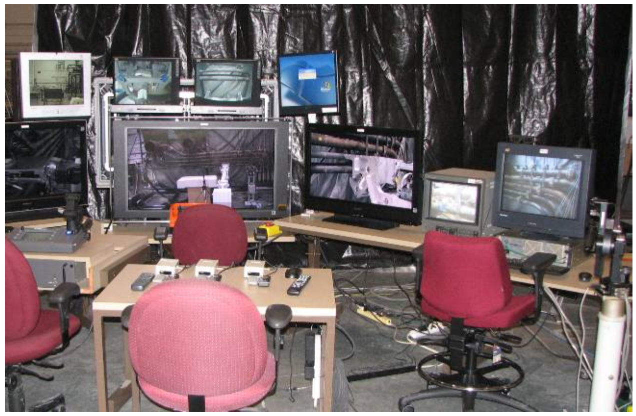

Figure 13: Control Center

VI. General comment about Feeder Removal

It must be recognized that feeder pipe removal somewhat resembles a demolition exercise. Application of the same Quality Assurance standards that are in place during the commissioning and daily operation of nuclear stations is unnecessary. The majority of the structures located at proximity of the work areas are either robust enough to resist any potential impacts during pipe removal, or are scheduled to be replaced. Mechanical protections will be installed for reactor components and structures that are to be reused and are deemed “at risk” of being damaged during pipe removal and inspections will be performed to confirm their integrity once the removal has been completed.

VII. CONCLUSION

This paper presents an overview of the work done by Hydro-Québec to develop an innovative method of removing the feeder pipes of a CANDU 6 nuclear reactor as part of a refurbishment project. The method, called Remote Feeder Removal (RFR), employs manipulator arms, an integrated vision system and specialized tools to perform the work. This keeps the operators away from the radiological zone, and thus reduces their estimated radiation exposure by a factor of seven in comparison to the manual removal method. Furthermore, the ideas presented in this document have been fully tested on a life-size physical mock-up to prove their feasibility and the complete removal scenario has been simulated in a virtual environment to visualize the entire RFR method.

Although this method was initially developed as a contingency plan to chemical decontamination, early reports showed significant advantages in using this RFR method regardless of the outcome of the decontamination exercise. In fact, the completed study shows that by using this new technology, plant operators could also save time and money, while reducing radiation exposure.

Finally, even though the majority of the technology presented herein was designed for a CANDU 6 reactor, it could be adapted to all CANDU reactor plants and possibly to other nuclear plants as well**.**

REFERENCE

[1] Technical Report: G2-APR-B233-33120-RAPP-003, "ÉTUDE DE FAISABILITÉ - Retrait mécanisé des Tuyaux d’Alimentation du Réacteur", revision 0, by Alain Drolet, June 2007.
[2] AECL Preliminary Assessment Document, 66RF-33126-ASD-004, Rev 1D1, Gentilly 2 Feeder Removal Assessment, Decembre 2007, Norm Korell.

[3] Technical Requirements: G2-APR-4-33120-SPEC-002, "Plan de coupe et séquence de retrait des tuyaux d'alimentation", revision 0, by Alain Drolet, September 2006
[4] Technical Report: G2-APR-B233-33126-RAPP-002, "Estimation de la durée et de la dose collective associée au retrait des TAR selon la méthode téléopérée", revision 0, by Pierre Gauthier, July 2007.