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REMOTE MONITORING DESIGN CONCEPTS FOR SPENT FUEL STORAGE FACILITIES

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Abstract

For the past two years Sandia National Laboratories (SNL) has been involved in developing and installing Remote Monitoring Systems (RMS) at a number of sites around the world. Through the cooperation of the various countries and facilities, it has been possible to collect data on the requirements and performance of these systems that are for monitoring the movement of spent nuclear fuel. The data collected shows that the front end detection method can be a very useful concept to reduce the amount of data that has to be collected and, more importantly, reviewed by inspectors.

Spent fuel storage monitoring is a major part of the non-proliferation monitoring that must be done since spent fuel is the by-product of all the power and research reactors worldwide. The movement of spent fuel is easier in many respects to monitor since it always requires protective shielding.

This paper will describe a number of the Remote Monitoring Systems that have been installed to monitor spent fuel movement and the resulting decrease in data from the use of a sensor-driven front end detection system. The reduction of the data collected and stored is also important to remote monitoring since it decreases the time required to transmit the data to a review site.

Introduction

The monitoring of spent nuclear fuel is an important aspect of the nuclear nonproliferation treaty. Power and research reactors create tons of spent fuel that must be verified and followed as it moves through the fuel cycle either to permanent storage or reprocessing. The very radioactive nature of the spent fuel provides one feature that can make the monitoring task somewhat easier. The movement and storage requires heavy shielding that varies from deep pools of water to very large transportation casks. Another feature about spent fuel storage is the nature of storage. Spent fuel is moved relatively infrequently because the movement task is so difficult. That means most spent fuel storage is static and the containment and surveillance (C/S) systems have long periods of time where there is no need to collect data.

The International Remote Monitoring Project (IRMP) began with that aspect of spent fuel C/S systems. The Remote Monitoring Systems (RMS) installed at the various test sites were designed to constantly monitor the storage areas and to only record data and images when there was something of significance to record. This approach to C/S systems is not new and is sometimes given the name of "front end" detection. Various safeguards agencies have tried to use front end detection video systems and mostly without a great deal of success because anything from personnel movement to light reflections from spent fuel storage ponds have triggered the video change detectors into recording large numbers of extra frames.

The RMS attempts to avoid extra recording of video images by the proper selection and placement of a network of sensors to determine when there is activity of significance that should be recorded. A front end detection system based on a suite of sensors makes it possible to reduce or eliminate the capture of meaningless video images and to reduce the review time of the significant images. The reduction of the collection of video images is important from some aspects which relate to the changes in technology to permit the acquisition, storage, and transmission of digital images. While not all storage sites will use video surveillance, the majority of sites will. Digital images require large amounts of computer storage and more time to send over narrow bandwidth channels such as telephone lines. This paper will examine how these design concepts have been and will be applied to four spent fuel storage sites in the IRMP.

DISCLAIMER

Storage Sites

Four sites which store spent nuclear fuel have been involved in RMS tests. The first site was the Dry Spent Fuel Storage Facility at the Australian Nuclear Science and Technology Organization (ANSTO) located near Sydney, Australia. A prototype RMS has been in operation since February, 1994. The spent fuel storage pond of the Barseback Nuclear Power Reactor near Malmo, Sweden has been under RMS test since August, 1994. The remotely located spent fuel storage at Embalse, Argentina has been using a non-video monitor system since March, 1995. It will be expanded soon to incorporate more sensors and a video system. An RMS was installed at a spent fuel storage pond at the Joyo facility in Japan during July, 1996. All of these sites have sets of different requirements but all can be met by the proper selection of sensors and their placement in the facility.

Dry Spent Fuel Storage Facility at ANSTO

A number of different sensors and detection devices have been installed at ANSTO to study how they can be used to complement each other for C/S applications. The Authenticated Item Monitoring System (AIMS) is used to monitor the storage pits. AIMS Sensor Transmitters (ASTX) containing motion sensors have been attached to the covers with Velcro. Any motion of the ASTX or the storage pit cover to which it is attached will generate an alarm signal which is transmitted over a radio frequency (RF) carrier to the receiver. A few of the ASTXs called AIMS Fiber Optic (AFO) seals are electronic seals which detect the status of a fiber optic loop.

The AFO seals send an alarm over an RF signal whenever the fiber optic loop is opened. Fifty AIMS transmitters are attached to the storage pits.

Microwave motion detectors are used to determine if any activity is occurring in the area. The microwave motion detectors send out RF pulses at approximately 10 GHz to detect motion in the area. Two microwave motion detectors are used to monitor the storage area. Prototype Radar Motion Detectors (RMD) from Lawrence Livermore National Laboratories (LLNL) have been installed to test their operation. The pulses emitted from these sensors are well below 1 microwatt and are spread over several GHz. Their coverage consists of a hemispherical shell around the sensor that has an adjustable radius out to 24 feet.

The video motion detector by Three Dimensional Interactive Space (3DIS) was installed as a pre-programmed node as part of the installation during the February installation and was available when the 3DIS video motion detection system was installed during September The 3DIS system is now reporting motion and the data is being logged by the RMS.

LLNL Electronic Seals were installed in February and activated during September, 1994 to verify that they were still operational. All electronic seals transmitted data properly to the RMS when they were opened and closed. Difficulty with the electronic seals was encountered after about a year of operation. The exact time period cannot be determined because there was no state of health message available from the seal itself.

Detection of any activity will trigger video recordings to be made on a Video Surveillance Unit (VSU) and RMS computer.

The RMS was installed without any problems except for the Radar Motion Detectors (RMD). The RMDs were prototype devices that were being installed for the first time in a metal-clad building. A number of overnight tests were required to eliminate random false triggers. Changes in network node software were made to eliminate most of the problems, but in the time available at the facility, one of the four RMDs had to be removed from the field trial. Later in the test another of the radar motion detectors had to be removed from the network due to high false alarm rates.

No AIMS transmitters have failed. One group of false alarms from AIMS apparently was caused by construction workers drilling holes in the rock outside the building.

Barseback Nuclear Power Reactor

The RMS was installed in August, 1994 at the Barseback Works located north of Malmo, Sweden. The Barseback Nuclear Power facility is ideal to test the concept of front end detection since the majority of activities of safeguard interest is the movement of spent fuel which occurs once a year.

The RMS at Barseback uses a network of nodes to collect data from microwave motion detectors placed to detect the entrance and exit of spent fuel casks through a hatch. The collected data from four microwave motion sensors are used to trigger video recordings. An AC mains power monitor sends signals over the network to a "loss of AC power" alarm box.

The microwave motion detectors attached to the network are used to determine if any activity is occurring in selected areas. The microwave motion detectors send out RF pulses at approximately 10 GHz to detect motion in the area. Two detectors cover the exit hatch. By placing the beams in this configuration, a video recording is made when a large object is present in the hatch area. A third microwave detector uses a beam to detect when the crane is moved into a position that might allow spent fuel handling activities to occur. Microwave detector number 4 is used to make a recording when there is activity in the cask loading area. These detectors have a number of adjustments for sensitivity and motion thresholds. In addition, the logic in the nodes can be programmed to require motion activity in an area for a specified time period before sending trigger signals. Detection of any activity will trigger video recordings to be made on a Video Surveillance Unit (VSU) and RMS computer.

Embalse Power Reactor

An RMS was installed at the Embalse Nuclear Power Station in Embalse, Argentina. The sensors at this site monitor the status of a sample of four Candu spent fuel storage silos. The silos are located in a contained outdoor site with the sensors mounted atop the silos.

Four sensors are used at each silo; two analog to measure gamma radiation and internal silo temperature, and two digital to detect motion and to report the cutting of an electronic fiberoptic seal. State of Health (SOH) is also reported by each sensor. Sensor information is transmitted to a data collection system via an RF link using a modified AIMS motion detector.

Joyo Power Reactor

An RMS was installed at the spent fuel storage pond at PNC's experimental reactor facility, Joyo, in Oarai, Japan in July, 1996. A neutron radiation detector were installed in the pool inlet channel to verify the passage of spent fuel assemblies. Two gamma radiation detectors and a laser photoelectric "break beam" sensor were installed to detect motion at the "Hatch Door" entrance to the storage pond.

Four microwave motion detectors are used to determine if any activity is occurring in the area. Two motion detectors, mounted high on the pond room walls, monitor the overhead crane and the transfer crane. Two additional microwave detectors mounted near the edge of the pool detect fuel handling activities. All detectors are capable of triggering the capturing of video images.

Test Results

The RMS at ANSTO has performed very well during the over two years of testing. It has been regularly interrogated from Albuquerque, NM, US and Canberra, Australia. It was also interrogated from Vienna, Austria for several weeks of tests. The RMS has worked without any major problems.

Most of the data transfer telephone calls to the RMS go through without any problems. However, it has been noticed that the failure to get calls through from Albuquerque generally happens during 0800 to 1000 hours US time. It is surmised that the data traffic to Australia is heaviest during this time period. International telephone communications were improved when a hardware encrypted modem was removed and the encryption was performed by the software in the computer. The baud rate was able to be shifted up to 9,600 baud from 2,400 baud increasing the data transfer by a factor of four.

The RMS at Barseback performed extremely well and provided valuable information for future safeguards applications.

Spent fuel was moved out of the reactor during the last part of October and the first part of November, 1994. The movement of one spent fuel cask into and out of the reactor hall took approximately 49 hours. During that time period the Modular Integrated Video System (MIVS) observing the area should have taken about 1000 pictures on two recorders. The RMS recorded 272 triggers from the four microwave sensors and took 141 pictures.

The data collected with the RMS in Sweden demonstrated that this type of system with a sensor network can be used to significantly reduce the number of pictures to be reviewed by an inspector, both during periods of low activity and during times of high activity, when work such as spent fuel movements is occurring. For example, during spent fuel loading operations the sensors did not show any activity during the evening and weekend hours. A review of the Video Surveillance Unit (VSU) tape for the same period verified that there was no activity. The data also demonstrated that sensors can be selected and placed so that the normal day-to-day activity in a facility will not cause images to be recorded. A review of the VSU tape showed that personnel could enter and move about the pool area without causing any triggers. None of the activities detected on the VSU tape would have caused triggering and were not of safeguards significance.

The RMS at Embalse has performed well and is providing valuable analog and digital information. The analog data gathered from the site have shown that the radiation levels in the silo are at a constant level and the temperature is cycling throughout each twenty-four hour period. The temperature monitoring is mainly used to show the system is operating properly. Most of the interrogation telephone calls to the RMS go through without any problems but at slower data transfer baud rate; 2400 compared to the usual 9600 used in an RMS system, due to marginal quality telephone lines.

The RMS at the Joyo facility has not been in operation a sufficient amount of time to determine the performance of the system, and to collect significant amounts of data.

Conclusions

The RMS has used a number of different sensors to monitor various spent fuel storage sites. Each sensor has a different characteristic that has to be taken into account depending on the layout of the area being monitored. The area to be monitored has to be studied carefully to determine what type of sensor or combinations of different sensors needs to be employed to ensure accurate surveillance of an area.

The tests have also shown that the combination of reliable sensors and a local operating network can provide the foundation for a good front end detection system to monitor nuclear spent fuel storage sites.

References

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