Implementation of a Data Analysis Software for the Remotely Transmitted Data of State of Health (SoH) from Containment and Surveillance Safeguards Systems Applied to Nuclear Power Reactors in Brazil and Argentina

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Abstract

Application of surveillance and containment systems is a relevant safeguards activity to maintain the continuity of knowledge on inventories and flows of nuclear material in nuclear power reactors. The current surveillance technology deployed at these facilities is called Next Generation Surveillance System (NGSS). The NGSS system includes a Digital Camara Interface (DCI) module to gather images from up to 32 NGSS cameras for later inspector evaluation. Equipment for verifying spent fuel assemblies discharged from the core to the spent fuel pond are also used at on-load nuclear reactors, e.g., the VXI integrated fuel monitor (VIFM). The NGSS cameras, its digital camera Interface modules and the VIFM are capable of remotely reporting variables to indicate whether the devices are working properly. The system is therefore called State of Health (SoH) of the nuclear safeguards deployed equipment. The purpose of the SoH system is to daily report the equipment operational status. The reported data is reviewed and evaluated by ABACC and IAEA independently and in case of failure the agencies can take expedite remediation actions. Currently, ABACC and the IAEA have arrangements with Argentina and Brazil for remote SoH data transmission from three selected nuclear power plants (NPP): Angra 2 in Brazil and Atucha 1 and 2 in Argentina. In the NPPs there are cameras and the DCIs connected to the SoH server. In addition, as Atucha 1 and 2 is an on-load reactor, the VIFM has also been connected for SoH data transmission. The SoH data is securely transmitted from the selected facilities in Argentina and Brazil to ABACC and to IAEA HQs using virtual private network (VPN) tunnels. ABACC developed and uses a SoH data analysis graphical review software for analysis and ease visualization warning of the operational status of the nuclear safeguard systems. The developed system is also able to warn the technical support team officers by mail. This paper describes the developed SoH data analysis software.

1. INTRODUCTION

Surveillance and containment systems are commonly used to maintain the continuity of knowledge of nuclear materials under safeguards in nuclear facilities such as nuclear power reactors and uranium enrichment facilities. The quadripartite agreement among Brazil, Argentina, the Brazilian-Argentine Agency for accounting and Control of Nuclear Materials (ABACC) and the International Atomic Energy Agency (IAEA) [1] stated that both ABACC and IAEA should avoid the unnecessary duplication of the applied safeguards measures. In that view, ABACC and IAEA share the use of surveillance and containment systems in the nuclear facilities in both countries.

Currently, ABACC-IAEA jointly use surveillance and containment (C/S) systems installed in the on-load power reactors of Atucha 1, Atucha 2 and Embalse in Argentina, and in the PWR power reactors of Angra 1 and Angra 2 and in the uranium enrichments plants in Rezende and in Aramar in Brazil. The surveillance systems currently deployed at the Brazilian and Argentine facilities is the New Generation Surveillance System (NGSS), composed of secure digital cameras and digital interfaces that gather the images from the cameras and store in SD cards. These images are periodically reviewed by inspectors from ABACC and IAEA. Due to its specific design, the so-called on-load reactors continuously discharge spent fuel (SF) elements from the core up to a daily basis frequency. To control the discharge and proper disposition of theses SF elements in the SF pond, a set of gamma and neutron detectors are deployed along the path of the SF elements from the reactor core to the pond. This set of detectors are connected to a centralized computer system that stores the counting results. This unattended monitoring system is called VXI Integrated Fuel System (VIFM) [2]. These systems are installed in the nuclear power reactors of Atucha 1, Atucha 2 and Embalse, and similarly to the NGSS the collected data are periodically reviewed by inspectors of both agencies.

In 2014, ABACC and the IAEA proposed to implement systems for the remote data transmission (RDT) of operational parameters collected from those safeguard systems installed at the facilities to both agencies' offices, with the objective of acquiring operational status, i.e., SoH information to identify operational issues and malfunctions in the installed equipment [3]. Although it is possible to implement a full-scale remote data transmission, including surveillance images and detection data from the facilities, in the early stage of the project only SoH information was agreed upon with the state authorities to be transmitted. The implemented RDT also allows the agencies to access the remote equipment to reconfigure and correct minor problems. As part of the agreement among the parties, state authorities of both countries should have access to ABACC´s Office in Brazil to audit the remote data transmission system to guarantee that only SoH information from the on-site systems is transmitted. The system was implemented in 2017 at Atucha 2 and Angra 2 nuclear power plants (NPP) and is called since then State of Health (SoH) system. In 2019, the Atucha I NPP was included in the SoH and in early 2022 the Embalse NPP was also included in the system.

2. SAFEGUARDS EQUIPMENT OPERATIONAL STATUS TRANSMITTED DATA - SOH

The SoH was designed as a computer system that collect and stores data from the NGSS and VIFM systems installed at nuclear facilities. The SoH downloaded data is analyzed to provide early warning of malfunctions of the equipment and also to provide information on the important activities conducted in the systems, as SD card change, data download, technician login, among others. SoH is composed of data collecting computers at the facilities, remote data transmission to a server installed at ABACC´s office and from this server to independent servers at each agency´s offices. Additionally, an auditing computer is made available for representatives of both state authorities where it is possible to audit all the transmitted data from the facilities to the remote monitoring server.

The system is also capable of accomplishing some remote maintenance and repair actions. The access to the remote systems for these purposes shall be conducted jointly by the two agencies with a previous communication of the requiring agency and authorization of the other agency. All data transmission is secured using Virtual Private Network (VPN) encrypted communication tunnels. All the remote access to the remote systems shall be informed in advance to the states authorities.

In late 2017, the SoH were installed at the nuclear power plants in Argentina and in Brazil to transmit SoH information from the installed surveillance systems composed of three digital cameras (NGSS DCM-C5) and a digital camera interface (DCI/DCR). The SoH data is transmitted twice a day to the remote monitoring server at ABACC´s HQs and retransmitted to both agency´s servers. A simple software [4] was developed at ABACC to analyze the data collected from the facilities. At that time, only a few parameters, the input current and voltage, battery voltage, internal current and voltage and coin cell voltage of the DCM-C5 cameras were analyzed to assess the operational status of the surveillance systems. Alarm thresholds for some of these parameters were set in the software. The software reports any event with out-of-boundary values and displays a red line in the screen.

3. DATA ANALYSIS SOFTWARE FOR THE OF SOH OF DATA FROM SG EQUIPMENTS

In 2019, considering the potential of the SoH data in providing important information on the operational status of the systems, ABACC specified and developed a comprehensive graphical software for the complete visualization and verification of the status of the C/S safeguards equipment deployed at the two nuclear power plants in Brazil and Argentina [5]. This software is called SoH Monitor and only authorized users can access its database.

The SoH Monitor reading module automatically reads the SoH data files from the facilities. The system analyses the acquired data in .XML or .TXT format, store the results in an encrypted SQL Server database and compares the values with pre-set alarms to provide color coded information through the graphical dashboard (Figure 1). During the data analysis, all abnormal events (warning and critical) informed by the SoH were color coded displayed at the dashboard. Critical events are shown in red and warnings in yellow for easy visualization. In the dashboard the user can acknowledge the receipt of the event and also close the follow-up of an event. In this case, the event is shown in a faded color. The SoH Monitor is also designed to send e-mails twice a day to selected users informing a list of events and information on warnings and critical events, if any, in the last 12 hours period. The system was developed to automatically identify data from new facilities or C/S systems based on the collected files. To add the new facilities is necessary to enter information for the new facilities and systems, e.g., name, location and other additional parameters.

The dashboard is composed of 4 main areas: monitored nuclear facilities (area 1), map panel with facilities locations (area 2) and plant status, status panel with color coded events (area 3) and events description list sorted by date (area 4). The dashboard also shows the number of not acknowledged and open warning and critical events.

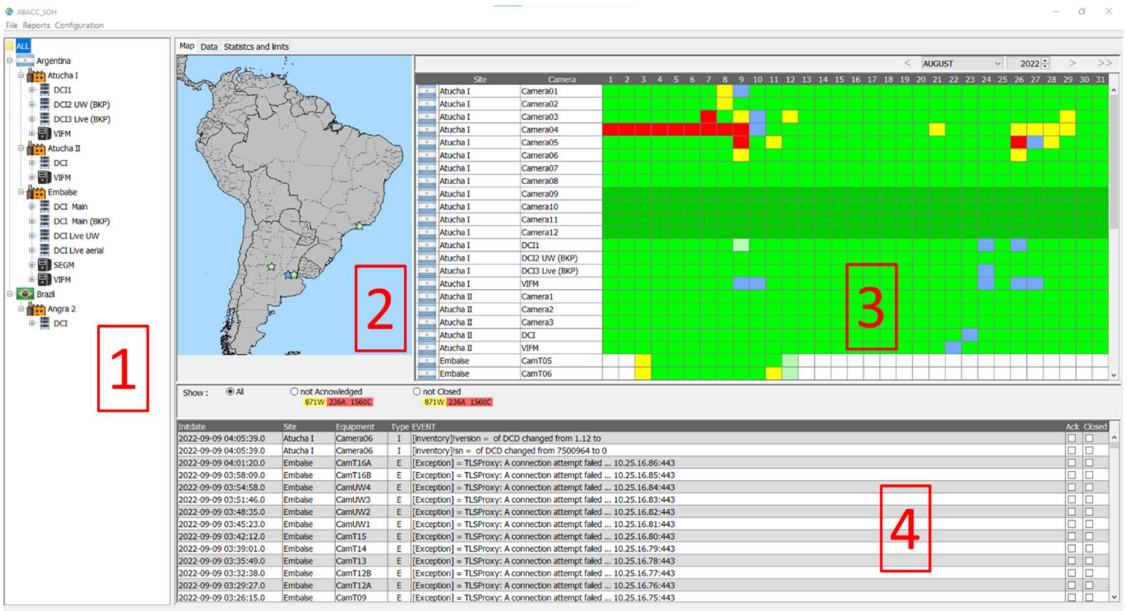

FIGURE 1 – Graphical dashboard of the SoH Monitor showing some critical, warning and important events. Faded colors are used for closed events.

ABACC conducted a first revision of the SoH monitor software in early 2020 to incorporate new features such as the possibility to modify the categorization of an event, despite its original category defined by the provider of the equipment and the capability of sending to the users more qualified information and a list of files read by the system by e-mail. Similarly, system messages are sent to the users twice a day.

The data screen of the SoH (Figure 2) presents the installed devices per monitored nuclear facility per country. The second column of this screen shows the devices and the attributes reported in the SoH transmitted data. The name and value of each attribute of an item of a device, e.g., inventory of the DCI/DCRs in a facility with name, serial number and date of change is displayed in the third column

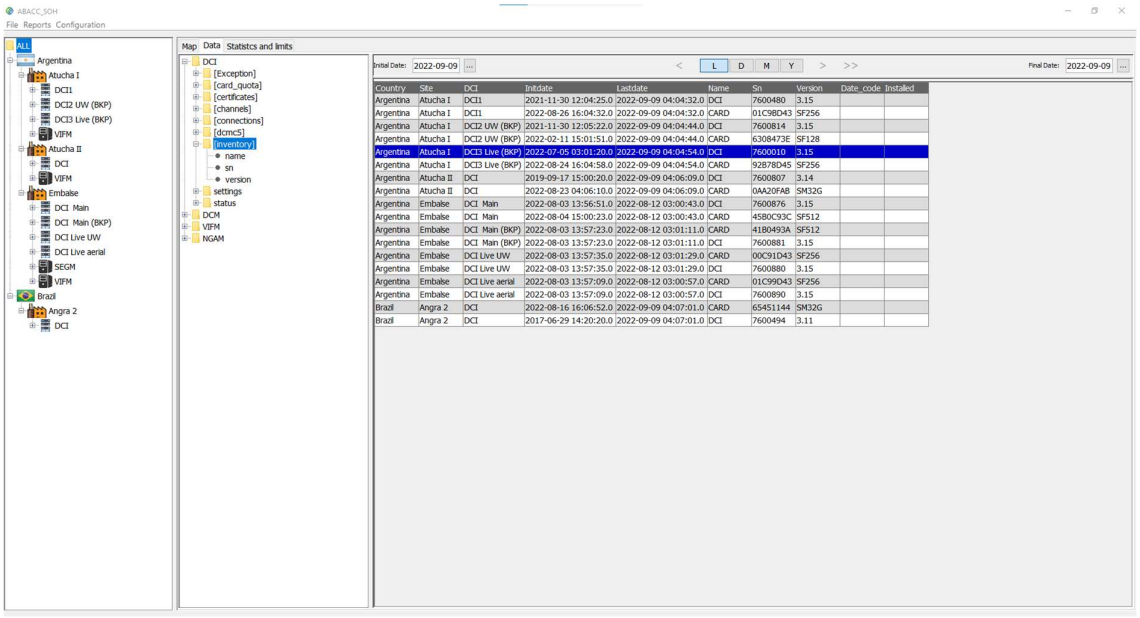

FIGURE 2 – Data Screen of SoH monitor

The SoH monitor is also capable of basic statistics calculation and plots (Figure3). The calculated values and plots can be filtered by facility, country or to all data available in the database. For every device important property, the software calculates and displays: unit, number of elements, maximum and minimum values, mean and standard deviation of the filtered set. The system will automatically produce a warning every time the value is outside the interval of the mean ±1 standard deviation, or alternatively, outside the informed lower and upper level.

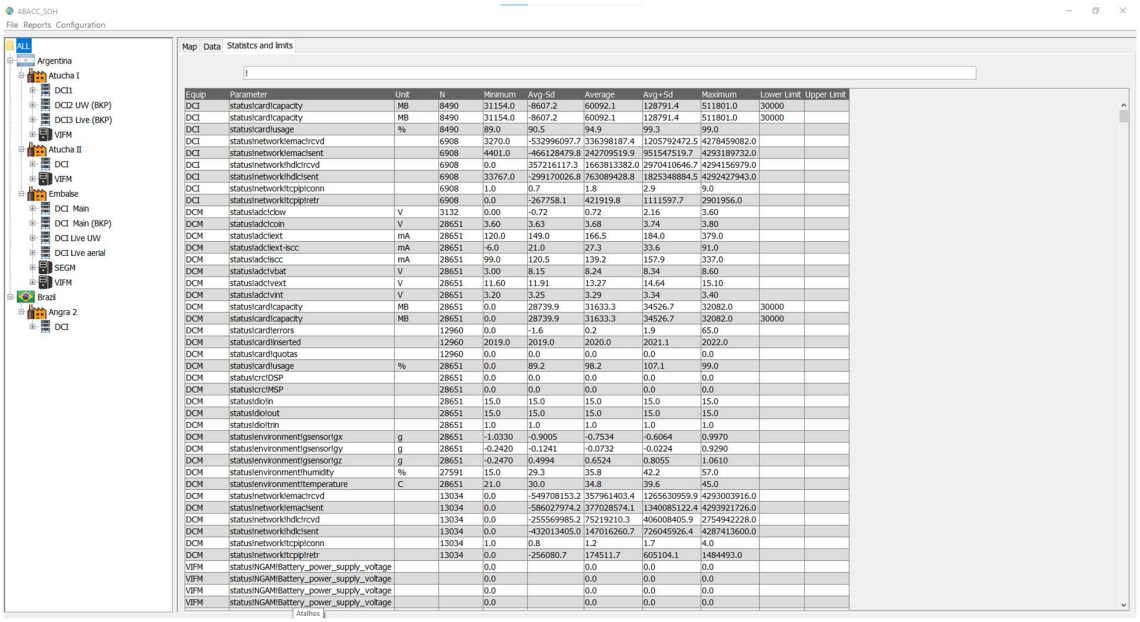

FIGURE 3 – Statistical data

The SoH also produces a monthly report, showing the dashboard with color coded events, a legend for the colors and the list of events and its description in that month, as seen in Figure 4.

MONTHLY REPORT EXAMPLE

Table 1 – Monthly report of the system status.

	Site	Camera	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Atucha II	Camera1																															
	Atucha II	Camera2																															
	Atucha II	Camera3																															
	Atucha II	DCI																															
	Atucha II	VIFM																															
	Angra 2	Camera1																															
	Angra 2	Camera2																															
	Angra 2	Camera3																															
	Angra 2	DCI																															

Legend

Type	Description	Event Open	Event Closed
-	No data for the equipment		
-	No events for the equipment		
-	One file missing		
-	Disabled event(s) occoured		
I	Important information		
W	Warning		
A, C	Limit exceeded or critical event		

Table 2 – List of events.

Initdate	Site	Equipment	Type	EVENT	Ack	Closed
1900-01-01 00:00:00.0	Atucha II	Camera1	W	Missing blocks: status, cert, performance, in file soh-2022-07-01-03-07-48.xml		
1900-01-01 00:00:00.0	Angra 2	DCI	E	[Exception] = TLSProxy: A connection attempt failed ... 10.6.32.2:443		
1900-01-01 00:00:00.0	Angra 2	Camera1	E	[Exception] = TLSProxy: A connection attempt failed ... 10.6.32.3:443		
1900-01-01 00:00:00.0	Angra 2	Camera2	E	[Exception] = TLSProxy: A connection attempt failed ... 10.6.32.4:443		

FIGURE 4 – Monthly Report example

The SoH can handle not only the collected data from the facilities, but also any operational status data collected from the facility during the regular inspections. Once the data is fed into its folder the system will automatically treat it the same way of a remotely collected data. This is of a particular interest to maintain a history of alarm, warning, inspections and technical activities conducted at that facility.

In 2021, during the installation of the safeguards Unattended Monitoring System (UMS) in the new SF dry storage facility of the Atucha I NPP the RDT was also implemented.

In 2022, during an upgrade of the safeguard surveillance system at the Embalse NPP, the RDT was made available to all the equipment connected to the UMS of the at this facility. In July 2022, the test period was initiated.

4. PLANNED NEW FEATURES

The SoH Monitor became a very useful tool for planning maintenance and even inspections activities, to react to warning and critical events with safeguards equipment and even to access the remote systems for configuration and limited maintenance.

Taking into account the relevance of the system and the growing of connected facilities, in 2022, a new version of the system was planned and will include new functionalities to the system such as: display of attributes and history of installed equipment, enhancement in the dashboard allowing a compact or expanded view of all, a more user-friendly interface, among others.

It is also planned to install standalone versions of SoH in facilities where the collection of data is not authorized by any digital means. In such a case a historical report of the health can be locally analysed by the inspectors or technicians and eventually printed to further investigation.

5. FINAL CONSIDERATIONS

The SoH system installed at the nuclear facilities under safeguards effectively provides early warning information on the operational status of the nuclear safeguards containment and surveillance systems. It plays an important role for implementation safeguards allowing a prompt response for critical failures and, in some cases, avoiding loss of the continuity of knowledge of the nuclear material under nuclear safeguards at the facilities.

It is noteworthy that the SoH plays an essential role in the regular use of safeguards equipment installed at nuclear facilities, moreover in plants where UMS system is implemented, and a quicker response to a failing equipment is foreseen.

The software specified and developed by ABACC proved to be very effective to monitor and analyse all the essential parameters of the C/S systems since its installation and played a very important role during the pandemics when the knowledge of the operational status of the safeguards C/S was essential.

Considering the large amount of data produced by the C/S systems, it is absolutely necessary the use of such a comprehensive software to deal with all the events and analyse the data produced by the RDT.

6. REFERENCE

[1] Quadripartite Agreement, Agreements between Republic of Argentina and the Federative Republic of Argentina and the Federative Republic of Brazil, the ABACC and the International Atomic Energy Agency (IAEA) for the application of safeguards, 1999, 1991.

[2] IAEA, Safeguards Techniques and Equipmant: 2011 Edition, Viena: International Atomic Energy Agency, 2011.

[3] ABACC, “Proposal for the Implementation of a SoH Transmission System, TNT-0034.04, E. Galdoz,” Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials, 2014.

[4] ABACC, “Software de análisis de los archivos recibidos por el sistema, TNT-0088.00, A. Bonino,” Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials, 2018.

[5] ABACC, “SOH_MONITOR V 2.0 Users´ Manual,” Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials, Rio de Janeiro, 2020.