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Four Years of Experience on State of Health (SoH) Remote Data Transmission of Surveillance 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 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 cameras for inspector evaluation. Equipment for counting 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 equipment. The purpose of the SoH system is to daily report the equipment operational status. The reported data is reviewed and evaluated by ABCC 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 two selected nuclear power plants (NPP): Angra 2 in Brazil and Atucha 2 in Argentina. In each NPP there are three cameras and the DCI connected to the SoH server. In addition, as Atucha 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 review graphical software for ease visualization and analysis of the operational status of the nuclear safeguard systems.

This paper describes the analysis of the remoted SoH data received at ABACC HQ, the developed software to carry out this analysis and the experience gained in nearly four years of SoH data evaluation.

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. In 1991, under a quadripartite agreement among Brazil, Argentina, the Brazilian-Argentine Agency for accounting and Control of Nuclear Materials (ABACC) and the International Atomic Energy Agency (IAEA) (Quadripartite Agreement, 1991) agreed to apply and accept safeguards to all nuclear materials in all nuclear facilities in the territories of Brazil and Argentina to verify the exclusive pacific use of these materials. The agreement also 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, there are ABACC-IAEA jointly use surveillance and containment (C/S) systems installed in the on-load power reactors Atucha 1, Atucha 2 and Embalse in Argentina, and in the PWR power reactors Angra 1 and Angra 2 and in the uranium enrichments plants in Resende and in Aramar in Brazil. The surveillance system 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) (IAEA, 2011). 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 implementation of a system for the remote transmission of operational parameters collected from the NGSS and from the VIFM systems to both agencies' headquarters, with the objective of acquiring state of health (SoH) information about these safeguards monitoring systems to receive alarm of malfunctions (ABACC, 2014). Although the system is also capable of transmitting images and detection data from the facilities, in the early stage of the project only SoH information was allowed to be transmitted. As part of the agreement among the parties, State authorities of both countries should have access to ABACC´s Headquarters in Brazil to audit the system to guarantee that only SoH information from the on-site systems is transmitted. The system was implemented in 2017 in the above referred facilities and is called since then State of Health (SoH) system.

The State of Health System - SoH

The SoH was designed as a computer system that downloads and stores data from the NGSS and VIFM systems installed in nuclear facilities. The 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 and technician login, among others. SoH is composed of data collecting computers at the facilities, a Remote Monitoring Server installed in a joint use communication cabinet at ABACC´s Headquarters and

SoH servers at each agency´s HQs. 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.

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 (ABACC, 2018) was developed at ABACC to analyze the data collected from the facilities. At that time, the input current and voltage, battery voltage, internal current and voltage and coin cell voltage of the DCM-C5 cameras were considered the most relevant parameters to assess the operational status of the surveillance systems, and alarm thresholds for each 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.

The Graphical interface – SoH Monitor

In 2019, considering the potential of the SoH in providing important information on the health of the systems, ABACC specified and developed a comprehensive graphical software program for the complete visualization and verification of the operational status of the C/S safeguards equipment deployed at the two nuclear power plants in Brazil and Argentina (ABACC, 2020). This software is called SoH Monitor.

The SoH Monitor reading module automatically reads the files of the SoH data collected in text or XML format from the facilities and stores the data in an encrypted SQL database. The system analyzes the acquired data and compares the values with preset 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 was also 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 it. In this case, the event is shown in a faded color. This SoH Monitor is also designed to send e-mails twice a day to selected users with 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. The SoH Monitor will require additional user information for new facilities or systems, e.g., name, location and other additional parameters.

The dashboard is composed of 4 areas: monitored nuclear facilities (1), map panel with facilities locations (2), status panel with color coded events (3) and events description list sorted by date. The dashboard also shows the number of not acknowledged and open warning and critical events. Figure 2 present an example of an output report. The SoH monitor is also capable of showing statistics and plots of any selected important parameter.

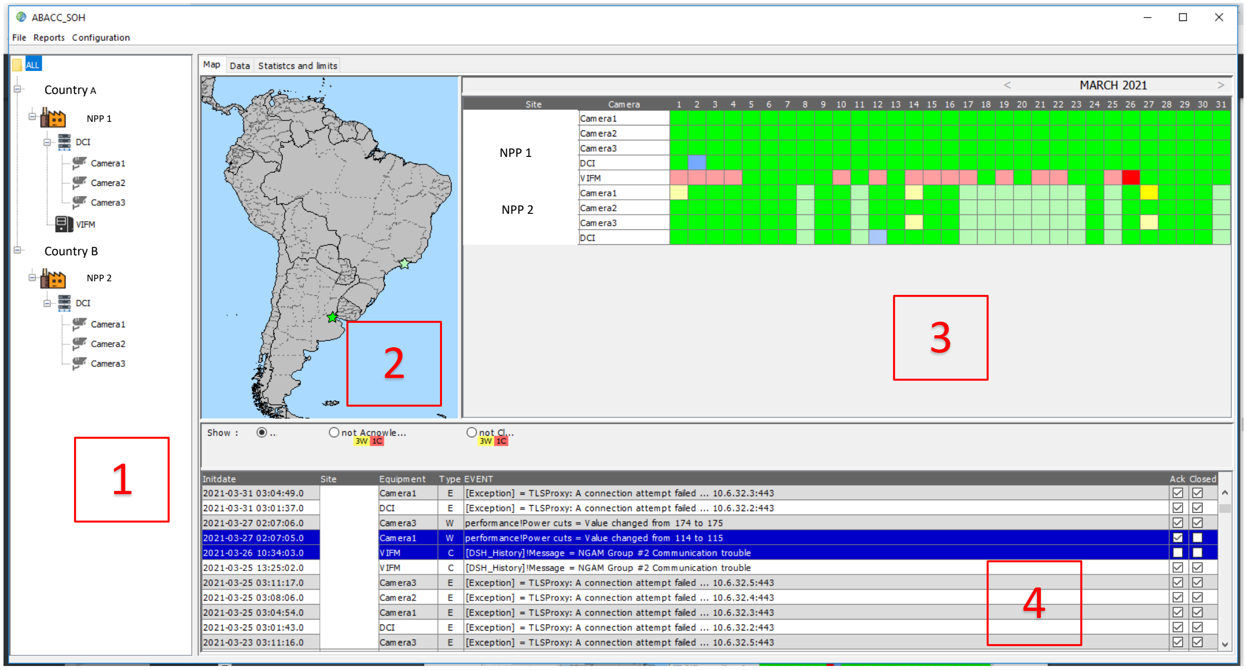
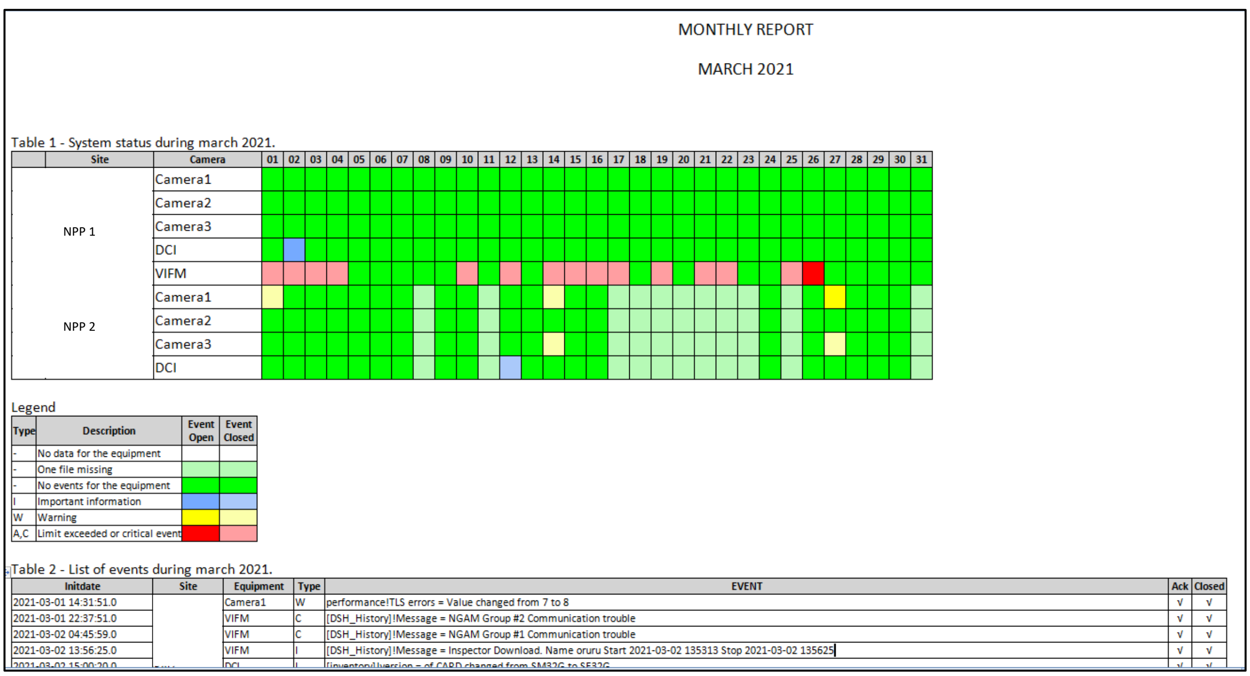


Figure 1 – Graphical output of the SoH Monitor showing some critical and warning events. Faded colors are used for closed events.



MONTHLY REPORT

MARCH 2021

Table 1 - System status during march 2021.

Site	Camera
NPP 1	Camera1
	Camera2
	Camera3
	DCI
	VIFM
NPP 2	Camera1
	Camera2
	Camera3
	DCI

Legend

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

Table 2 - List of events during march 2021.

Initdate	Site	Equipment	Type	EVENT	Ack	Closed
2021-03-01 14:31:51.0		Camera1	W	performance!TLS errors = Value changed from 7 to 8	√	√
2021-03-01 22:37:51.0		VIFM	C	[DSH_History]!Message = NGAM Group #2 Communication trouble	√	√
2021-03-02 04:45:59.0		VIFM	C	[DSH_History]!Message = NGAM Group #1 Communication trouble	√	√
2021-03-02 13:56:25.0		VIFM	I	[DSH_History]!Message = Inspector Download. Name oruru Start 2021-03-02 135313 Stop 2021-03-02 135625	√	√

Figure 2 – Monthly Report example

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 and the capability of sending to the users more qualified information and a list of files read by the system by e-mail. Similarly, the collected data messages are sent to users twice a day.

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 2.

Four years of operation – examples

The output of the first software developed at ABACC is shown in Figure 3, reporting an abnormal event, on December 2nd, 2017 with the camera 1 of the NPP 1. An input current with a value of 202 mA were measured at the camera and collected by the SoH. This value was compared to the threshold of 200 mA for this parameter and triggered an alarm. This value was greater than the threshold of 200 mA set for this parameter and triggered an alarm, showed by red line at the bottom of the screen.

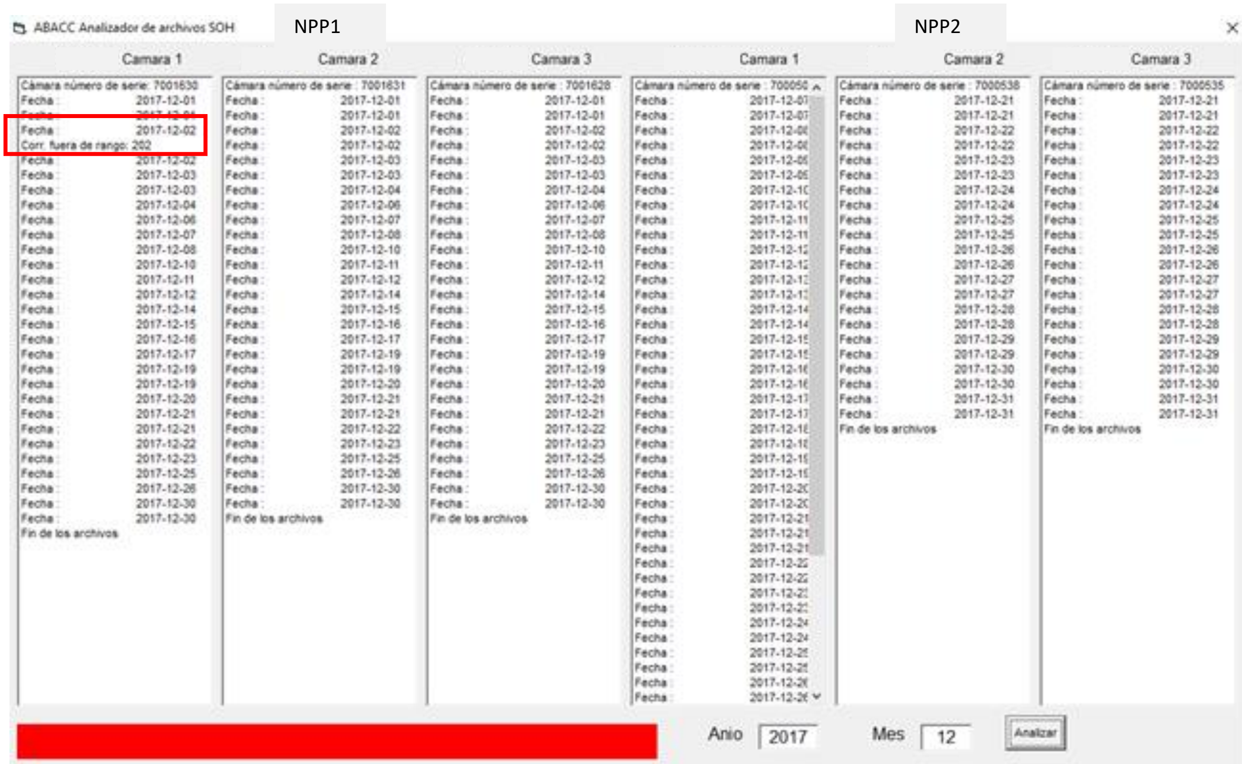


Figure 3 – Display of initial software showing a triggered alarm

The Figure 3 also shows, in December 21st, 2017, the beginning of SoH data transmission of cameras 2 and 3 installed at NPP 1. Although a simple software, it was very effective to monitor the essential parameters of the surveillance system.

Figure 4 shows the dashboard of the new developed software for May 2019. That figure shows the repeated occurrences of a VIFM “DB Processor trouble” of the NPP 1. This was a critical event and demanded an intervention at the site to fix the problem. The detectors´ acquisition module was changed and the VIFM resumed to its normal operation. An initial technician intervention on May 13th, 2019 may also be observed in the dashboard, as well as the final technician login in the system on May 24th, 2019 and no other problems with the VIFM database were reported.
In this example the SoH Monitor read the file and verified the occurrence of a critical event that could compromise the operation of the VIFM and effectively inform visually and by message.

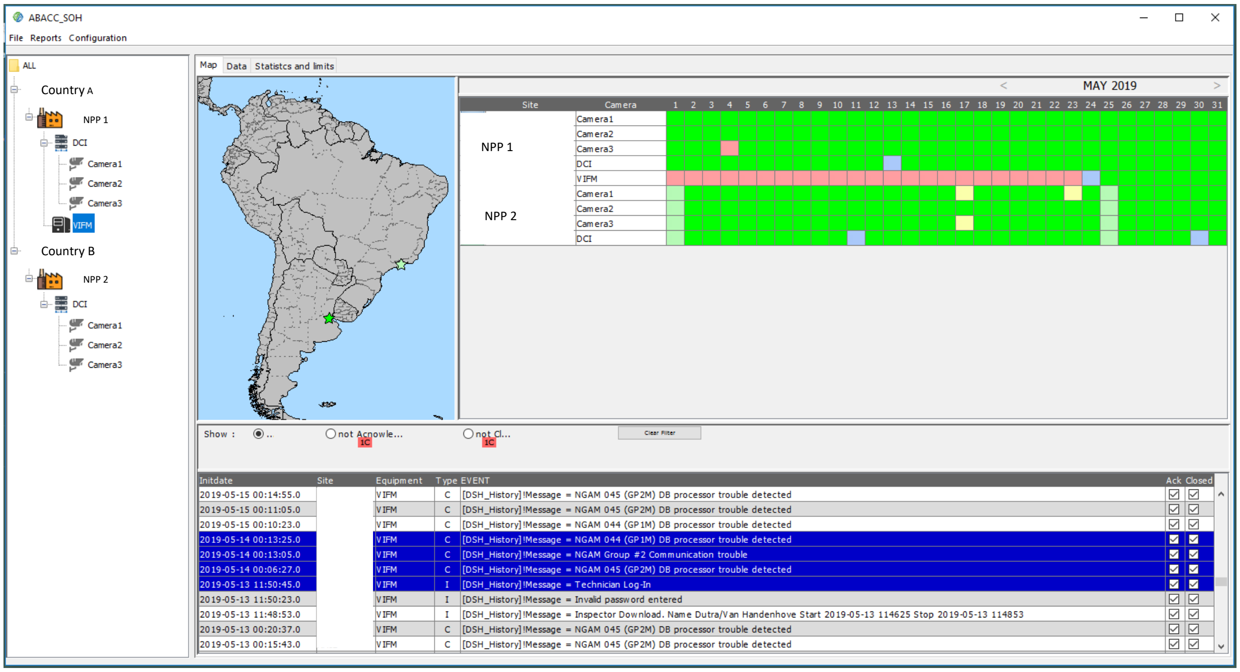


Figure 4 – Example of a critical event at the VIFM

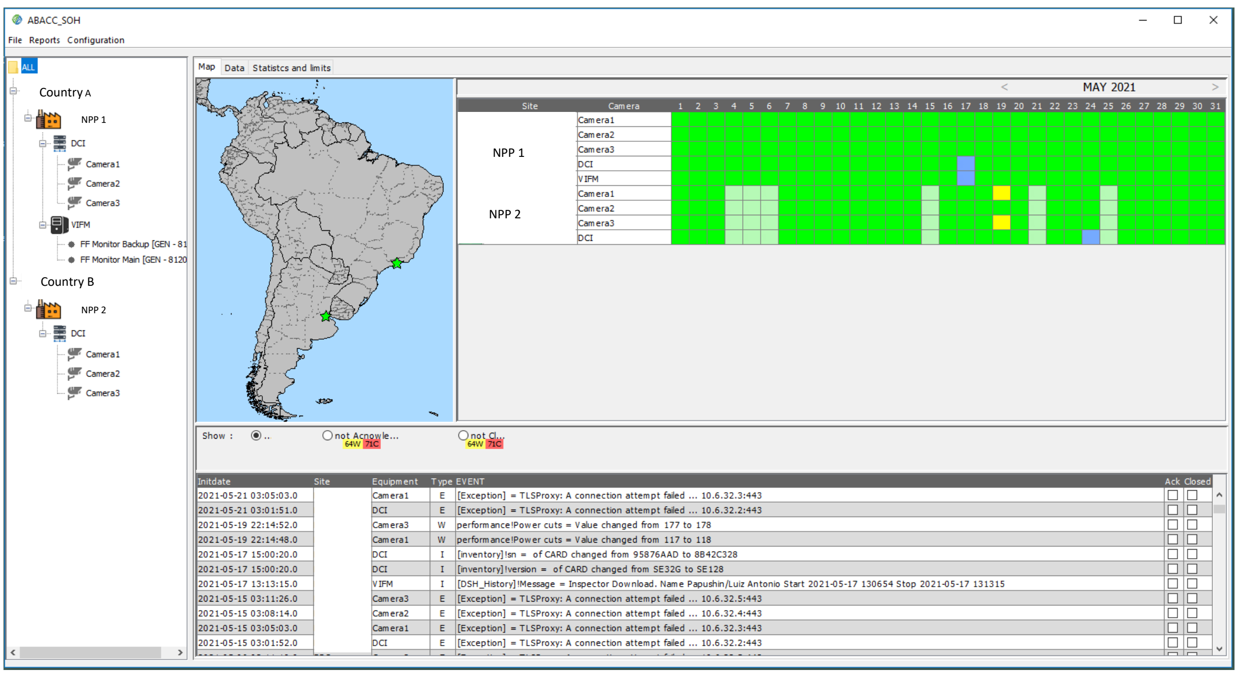


Figure 5 – Example of inspections activities in nuclear power plants

Figure 5 displays the SoH dashboard for May 2021, where different events may be seen. The downloading of data from the VIFM by an inspector and the changing of the SD card at the DCI were registered in NPP 1 on May 17th. Power cuts in the Cameras 1 and 2 of NPP 2 were registered on May 19th. These power cuts are considered warning events by the SoH and do not affect the functionality of the system, that can operate on batteries. There was also inspection´s activities on May 24th, which included the changing of the SD card.

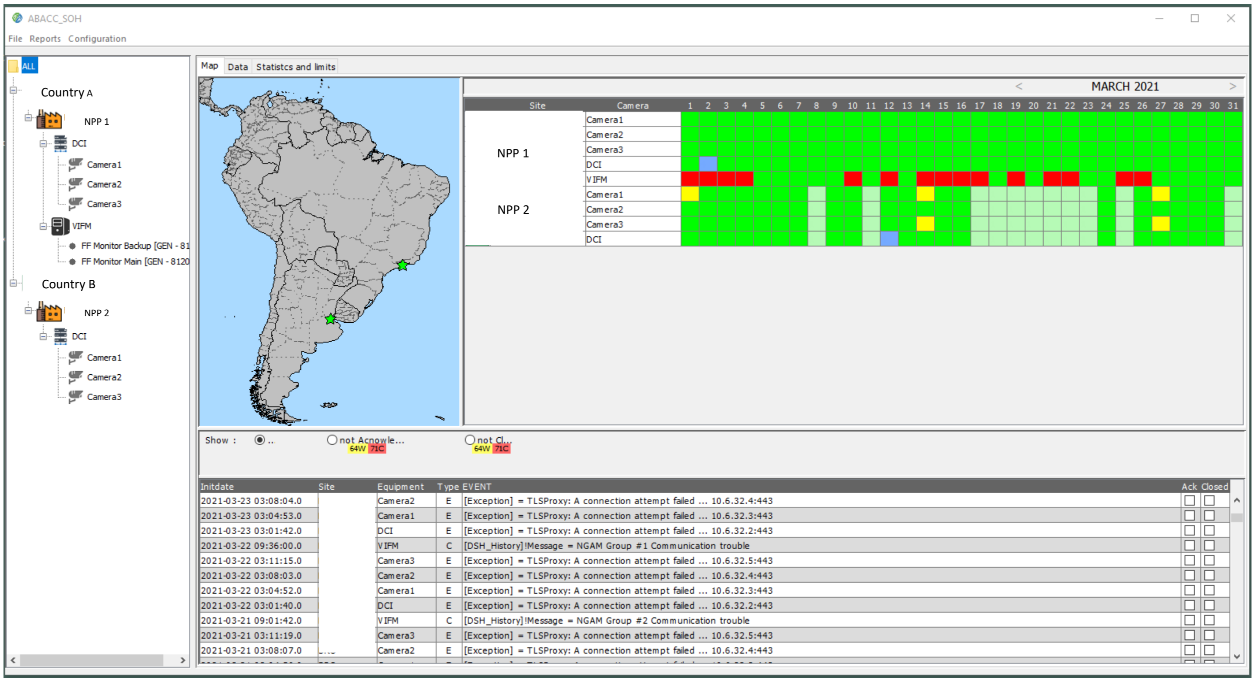


Figure 6 – Example of considered non-critical events at the VIFM

The figure 6 shows critical events for the VIFM of NPP 2 from March 1st to 26th. The description of the events was informed as a "trouble of communication". These events are considered critical by the VIFM, but reclassified by the technicians as non-critical, based on the fact that data was not lost and it was later recovered by the system. This is a well-known fault of the USB driver of the equipment that will be fixed with a new version of the equipment´s firmware. This dashboard also shows inspection's activities at the DCI on both NPP and power cuts at the cameras of NPP 2.

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.

The software specified and developed by ABACC proved to be very effective to monitor all the essential parameters of the C/S systems. Considering the large amount of data produced by the C/S systems, it is absolutely necessary the use of a comprehensive software to deal with all the events and analyze the data produced by the SoH.

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