CENTRAL ALARM SYSTEM REPLACEMENT IN NPP KRŠKO

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ABSTRACT

Current NPP Krško central alarm system consists of three main segments: Main Control Board alarm system (BETA 1000), Ventilation Control Board alarm system (BETA 1000) and Electrical Control Board alarm system (BETA 1100). All sections are equipped with specific BetaTone audible alarms and silence, acknowledge as well as test pushbuttons.

The main reason for central alarm system replacement is system obsolescence and problems with maintenance, due to lack of spare parts. Other issue is lack of system redundancy, which could lead to loss of several Alarm Light Boxes in the event of particular power supply failure.

Current central alarm system does not provide means of alarm optimization, grouping or prioritization.

There are three main options of central alarm system replacement: Conventional alarm system, hybrid alarm system and advanced alarm system. Advanced alarm system implementation requires Main Control Board upgrade, integration of process instrumentation and plant process computer as well as long time for replacement. NPP Krško has decided to implement hybrid alarm system with patchwork approach. The new central alarm system will be stand alone, digital, with advanced filtering and alarm grouping options. Sequence of event recorder will be linked to plant process computer and time synchronized with redundant GPS signal. Advanced functions such as link to plant procedures will be implemented with plant process computer upgrade in outage 2006.

Central alarm system replacement is scheduled in outage 2004.

1 INTRODUCTION

Alarm systems are one of the key elements in nuclear power plant control rooms because of the complexity of the process being controlled. The alarm system is one of the primary means by which process abnormalities and failures are brought to plant personnel's attention.

Basic alarm system consists of three major subsystems as seen in Figure 1:

- an auditory alert subsystem
- a visual alarm subsystem
- an operator response subsystem

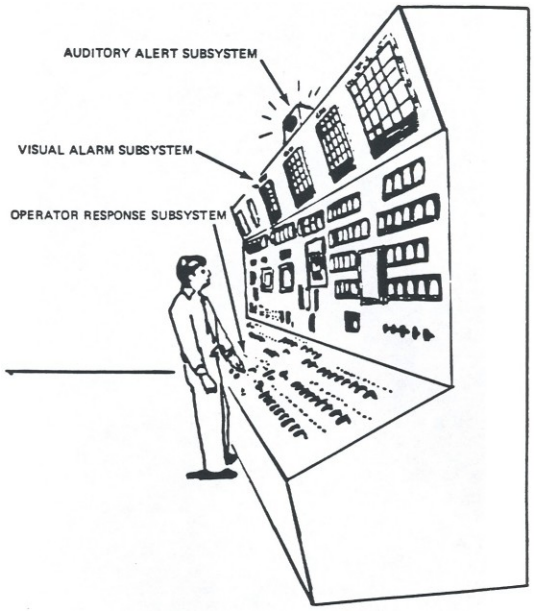

Figure 1. MCB Annunciator warning system

According to priority, alarms can be grouped into three levels as shown below.

First priority alarms:

- plant shutdown
- radiation release
- plant condition which, if not corrected immediately, will result in automatic plant shutdown or radiation release, or will require manual plant shutdown

Second priority alarms:

- Technical Specification (TS) violations which, if not corrected, will require manual plant shutdown
- plant conditions which, if not corrected, may lead to plant shutdown or radiation releases

Third priority alarms:

- plant conditions representing problems (e.g. system degradation) which affect plant operability but which should not lead to plant shutdown, radiation release, or violation of TS

2 NPP KRŠKO CENTRAL ALARM SYSTEM

NPP Krško uses conventional central alarm system which consists of three main segments located in the Main Control Room:

- Main Control Board alarm system (BETA 1000)
- Ventilation Control Board alarm system (BETA 1000)
- Electrical Control Board alarm system (BETA 1100)

The central alarm system is designed to provide visual and audible annunciation of off-normal conditions of any device by monitoring the state of switches, which will change state when annunciation is required. Annunciation is accomplished by employing high noise immune logic and related circuitry to light an engraved window for each point being monitored and sound a horn.

The BETA 1000 series remote annunciator system consists of two basic parts:

- an equipment cubicle containing power distribution panel, logic system, lamp connector panel, field input terminals, reflash housing, and relay housings, and
- remote lamp housings containing the indicator lamps behind engraved nameplates

The equipment cubicle and remote lamp boxes are connected by prefabricated plug-in cables.

Main Control Board (MCB) alarm system consists of three central panels, 19 annunciator light boxes and five BetaTone horns (different for each MCB section). Each Main Control Board section has its own set of pushbuttons for Silence, Test and alarm Acknowledge.

Alarm Light Box 10 on MCB section C is specific, as it provides information about First Out alarms. MCB section C is therefore equipped with an additional pushbutton "First Out Acknowledge", to prevent Acknowledge pushbutton from turning off the First Out annunciator when acknowledging other alarms on this section (ALB 6 through ALB 11). This additional pushbutton is protected by transparent cover to prevent spurious acknowledge.

Ventilation Control Board alarm system consists of one central panel (BETA 1000) and six Alarm Light Boxes with one common BetaTone horn. The total number of alarm windows handled by this system is 232.

Electrical Control Board alarm system is a small set of three Alarm Light Boxes with total of 42 alarm windows driven by one BETA 1100 series central panel. ECB alarm system uses one BetaTone horn for audible annunciation.

Total number of alarm points handled by NEK's central alarm system is 1114.

3 PROBLEMS WITH THE CURRENT CENTRAL ALARM SYSTEM

The main reason for central alarm system replacement is system obsolescence and unreliable operation which could lead to manual plant shutdown in the event of multiple alarm activation, especially on the First Out section. There are problems with maintenance, due to lack of spare parts. Over the years NEK has experienced several spurious alarms or horn activations without apparent reasons, so NEK I&C department issued request for central alarm system replacement.

Current system is not flexible for configuration changes. There are limited options available for changing or adding additional inputs, such as adding additional reflash capabilities to an alarm window.

There is also lack of system redundancy. The basic system design contains multiple single points of failure, where the entire system can be lost. For example, particular power supply failure could lead to loss of several Alarm Light Boxes.

The whole alarm system is not centralized. Moreover, subsystems for MCB, VCB and ECB are of different types.

Current central alarm system does not provide means of alarm optimization, grouping or prioritization.

The central alarm system issue is at the top of the NEK Top 10 open problems list.

4 OPTIONS FOR CENTRAL ALARM SYSTEM REPLACEMENT

There are two main options for central alarm system replacement:

- integral approach: alarm system replacement with system as part of integrated instrumentation platform
- patchwork approach: alarm system replacement with stand alone system (system is not an integrated part of the instrumentation platform; further integration would be harder and not complete)

4.1 Conventional central alarm system

One of the options was to replace current central alarm system with the similar one, with some level of system redundancy.

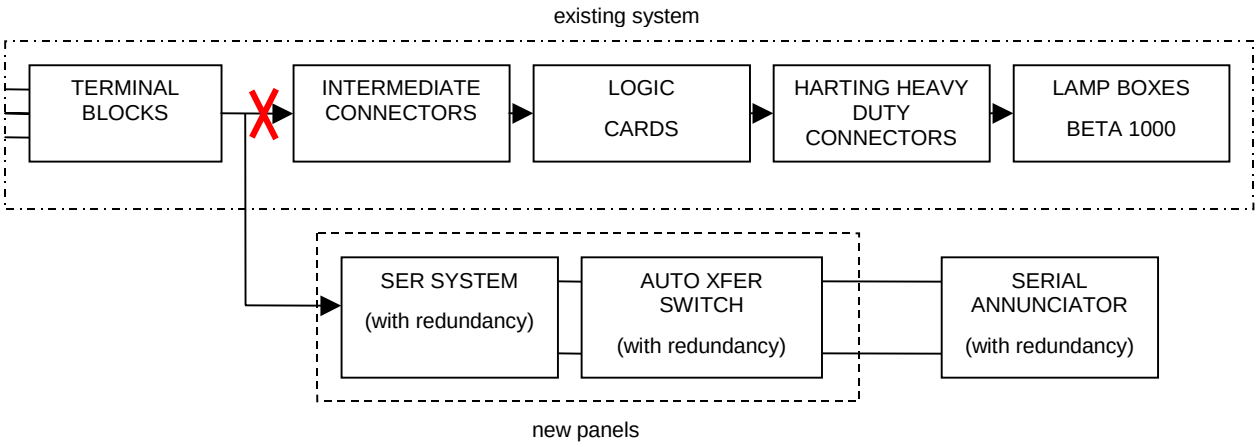

Figure 2. Conventional Central alarm system replacement option

This approach would solve problems regarding maintenance and system obsolescence but would not improve interface to the operators or introduce new functions for alarm management. This would certainly be the easiest solution.

4.2 Advanced central alarm system

Since Three Mile Island accident in 1979, nuclear utilities have recognized an important factor: The number of alarms and their presentation during transients or accidents may affect operator's ability to collect and respond to information effectively. In the worst cases, these situations lead to damage of equipment and extended downtime.

The need to improve the human factors engineering of alarm systems has led to the development of advanced, computer-based alarm systems. The goal of such systems is to assist the operator by processing alarm data, and to improve the presentation of this information. This technology promises to provide a means of correcting many known deficiencies in alarm systems. Advanced, computer-based alarm systems are available as upgrades to existing human-system interfaces, and are included in new control room designs (such as Westinghouse AWARE system as part of AP600 concept).

Advanced alarm system enables state of the art techniques for alarm processing and presentation.

Main features of advanced alarm systems include:

- reduced number of alarm indications
- dynamic prioritization: event independent prioritization, locally within categories, providing the most relevant overall set of alarms on the overview panel at each point in time
- dynamic sensitivity: reduces the number of alarms during large disturbances while maintaining sensitivity during small disturbances, for early detection and correction
- functional layout: present abnormalities in a meaningful context
- integrated overview and detail displays

Implementation of advanced alarm system requires MCB upgrade and integration of the process instrumentation and plant process computer. Such modification requires long time for development of the model and concept.

According to EPRI research, time for development, manufacturing and implementation is more than 4 years. Advanced alarm system causes great secondary impact on MCB, simulator, procedures and documentation. Furthermore it is related to considerable costs (4-7 million $).

4.3 Hybrid central alarm system

Hybrid central alarm system is a combination of a digital monitoring and control system operating alongside conventional alarm system.

Choice of hybrid alarm system enables:

- fast development
- relatively easy replacement
- option for advanced alarm filtration/suppression

Link to Plant Process Computer enables additional functions:

- alarm distribution over process computer network
- link to plant procedures, alarm setpoints and drawings

Hybrid system has rather small secondary impact, but enables further upgrades and integration with process instrumentation for the purpose of advanced alarm processing, for which additional context sensitive signals are required. These upgrades can be performed in several phases by modules, as additional signals are activated. At last, implementation of hybrid central alarm system is significantly cheaper than implementation of advanced alarm system.

5 MODIFICATION DESCRIPTION

The goal of the modification is to integrate MCB, VCB and ECB alarm subsystems into one central system which would provide operators with reliable and redundant alarm information.

The basic criteria for central alarm system replacement were:

- system reliability
- system redundancy (fully redundant system, powered from two independent power supplies with system redundancy up to the alarm light)
- time required for development, manufacturing and implementation (system is scheduled for replacement in outage 2004)
- price

Additional criteria:

- possibility for future enhancements and upgrades (advanced alarm processing, alarm message presentation, connection to the plant process computer)
- secondary impact (Main Control Board, NEK simulator, procedures, documentation, training)

As a result of thorough evaluation NEK has decided to implement a hybrid, fully redundant and centralized annunciator system with:

- option of advanced static and dynamic filtering
- on line diagnostics (functional tests, status and error reporting)
- built in option for alarm grouping and suppression
- connection to plant process computer for further enhancements (distributed alarm presentation over process computer network, link to alarm response procedures, setpoints and drawings)

The new system will be stand alone, specialized with future link to plant process computer. Redundant GPS IRIG-B signal will be used for precise time stamping of the events.

New central alarm system will consist of three main cabinets R1, R2 and R3 with Remote Configuration Workstation and Electronic Display Unit.

Remote logic cabinets will be located in the cable spreading area below the Main Control Room with prefabricated connecting cables.

First option was to install remote logic cabinets inside the control board cabinets, beneath control switches, but this would make maintenance more difficult due to lack of free space and would cause disturbance to the operating crew.

All ALBs (19 MCB + 6 VCB + 3 ECB) will be replaced with the new ones of the same dimensions, with redundant logic, lamps and drivers.

Existing FC terminations will be connected to the new R1, R2 and R3 scanner modules.

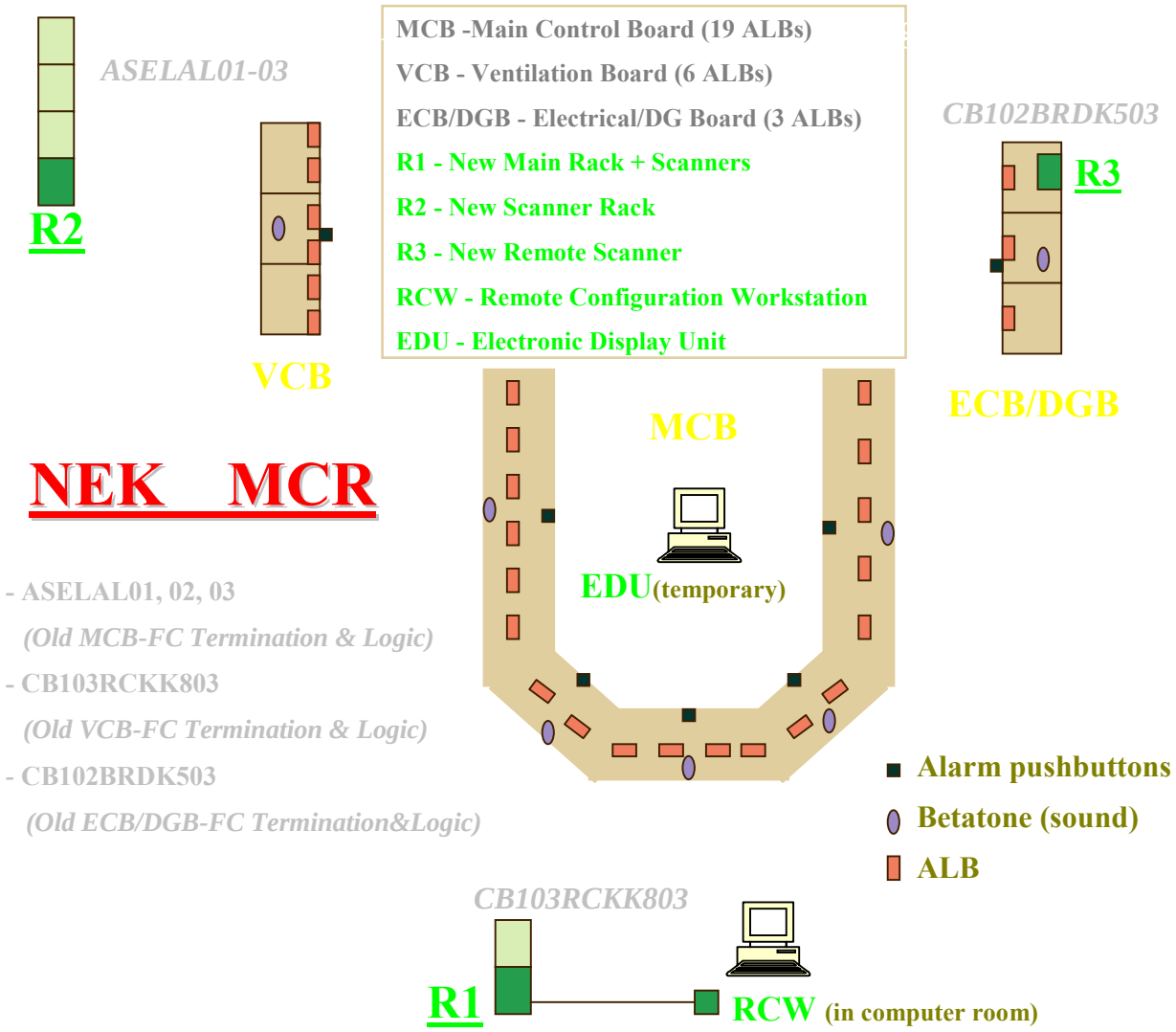

Figure 3. New Annunciator system – Equipment Arrangement

5.1 Remote Configuration Workstation (RCW)

The Remote Configuration Workstation (RCW) is a stand-alone computer program that:

- provides a means of configuring Sequential Event Recorders (SER), Alarm Filter (UMUX) Units, and serial input Distributed Annunciators from local or remote sites
- stores device configuration data on a hard disk for convenient downloading in case of device memory failure or replacement
- uploads and downloads configuration data between the hard disk storage and device configuration memory system
- allows configuration data to be viewed, edited, and printed
- archives SER events to the computer hard disk for analysis

- retrieves SER and Distributed Annunciator status information for viewing and printing

RCW supports up to 32 SERs and dial-up access to devices via modem. Remote and local SERs can be polled at independent polling rates. Multiple SER events can be examined in merged, time-sorted manner. SER events can also be exported to text file for further analysis.

After software migration to windows platform, RCW will be used for alarm presentation over the Process Computer Network until PIS upgrade in outage 2006.

5.2 Electronic Display Unit (EDU)

During the Central Alarm System replacement, operators will be using EDU for on-screen alarm presentation.

EDU provides an operator interface for color CRTs that are connected to event recorders. The controller allows the operator to control the display of alarm information on the screen of a color CRT. It operates by translating a pushbutton press by the operator into a hexadecimal code, which is transmitted to the event recorder via either RS-232 or fiber optics. When the code is received by the event recorder, the SER will update the screen of the color CRT depending on which key was pressed.

EDU enables alarm color coding by using eight different colors. Functional keyboard enables group selection and alarm management:

- 1st page: This key displays the first page of alarms when there is more than 1 page of alarms. A "page" is described as the number of alarms, which will fit on the CRT screen at one time.
- ACK: This key acknowledges any alarms on the visible page, which have not been acknowledged. Unacknowledged alarms are denoted by the flashing background under the time of alarm. This key has no effect on points which are not displayed on the screen at the moment of the keypress (i.e. points on other pages are not affected).
- ALARM: This key will cause the CRT to display only alarms. Returns to normal will not be displayed. Pressing ALARM key again will display all alarm data again.
- LOCK: This key "locks" the screen so that what is on the screen at the time of the keypress remains there and will not be pushed down to a lower page as new alarms come in. All other keys of the CRT controller will be ignored until LOCK is pressed again.
- NORMAL: This key causes the CRT to display only those points, which have returned to normal. No alarm data will be displayed.
- PAGE DOWN: Pressing the PAGE DOWN key will display alarms older than the ones currently displayed (roll over is enabled).
- PAGE UP: Pressing the PAGE UP key will display alarms newer than the ones currently displayed (roll over is enabled).
- RESET: This key will clear points on the CRT screen, which have returned to normal and have been acknowledged (i.e. steady green alarms). Note that this key has no effect on points which are not displayed on the screen at the moment of the keypress (i.e. events on other pages are not affected).
- BLACK, BLUE, CYAN, GREEN, MAGENTA, RED, WHITE and YELLOW: These keys cause the CRT to display only those points (either alarms or returns to normal) which have their legend background color defined as blue.

This unit will be temporarily installed at the shift foreman's desk. It could later be used for remote alarm presentation until RCW software migration to windows platform and future PIS upgrade.

6 FUTURE IMPROVEMENTS TO THE NEK CENTRAL ALARM SYSTEM

6.1 Installation of the PIS data link

The connection between the new Central Alarm System and PIS system will be implemented via Ethernet network connection using TCP/IP protocol. The estimated number of input points to be transferred from Central Alarm System to PIS will be 1200 points. All data transfers will be unidirectional, i.e. data will only be transferred from the new Central Alarm System to PIS, and no data will be transferred in the opposite direction.

Both PIS and the new Central Alarm System will be redundant. The new Central Alarm System will be equipped with two network controllers (one active and one in hot standby), which will be connected to PIS Level 2 via the switch. When started up or trying to reconnect, the client (Central Alarm System) will try to establish connection to both PIS servers via both network controllers. The server side (PIS) will try to determine which PIS server is active and use it for data transfer.

The new Central Alarm System and PIS will be synchronized to the same redundant signal source (GPS IRIG-B).

Installation of the PIS data link will be realized after plant process computer (PIS) replacement during 2006 outage.

This new features will allow for distributed alarm status display over the Process Computer Network, which will enable shift supervisor as well as shift engineer to remotely asses the status of the plant, without disturbances to the operating crew.

One of the biggest improvements in the alarm assessment for the operating crew will be introduced through link with Alarm Response Procedures, alarm setpoint lists and various system drawings.

6.2 Advanced alarm filtering, suppression and grouping

When a nuclear plant experiences a transient such as a trip, hundreds of alarms often occur in the first several minutes of the upset, creating an alarm overload that degrades the effectiveness of the system in conveying potentially important information to the control room operators.

The 1994 explosion and fires at the Texaco Milford Haven refinery injured twenty six people and caused damage of around £48 million and significant production loss. Key factors that merged from the Health and Safety Executive's investigation were:

- There were too many alarms and they were poorly prioritized.
- The control room displays did not help the operators to understand what was happening.
- There had been inadequate training for dealing with a stressful and sustained plant upset.

In the last 11 minutes before the explosion the two operators had to recognize, acknowledge and act on 275 alarms.

World experience suggests that the long term average alarm rate during normal operation should be no more than one every ten minutes and no more than ten displayed in the first ten minutes following a major plant upset.

Many alarm-processing schemes have been developed to address the alarm overload problem in nuclear plants, but very few of these approaches have been implemented in operating U.S. plants. Many plants still use conventional annunciator systems, which are very limited in alarm processing and logic capabilities; and utilities are reluctant to invest the considerable time and money that seem to be required to define and implement plant-wide alarm reduction. However, the newer digital monitoring and control systems now

operating alongside conventional equipment in "hybrid" control rooms provide much more capability to implement alarm processing. At the same time, there is a tendency for alarms to proliferate with such systems because of the ease with which new alarms can be generated in digital systems.

The new NEK's hybrid central alarm system will be equipped with several new features (filtering, suppression, grouping, local first out, etc.) that will require time and strategy for implementation.

An improved control room alarm system can greatly assist an operating crew during normal and transient plant operations.

7 ABBREVIATIONS

ECB - Electrical Control Board
EDU - Electronic Display Unit
GPS - Global Positioning System
MCB - Main Control Board
MCR - Main Control Room
NEK - Nuklearna Elektrarna Krško
NPP - Nuclear Power Plant
PCN - Process Computer Network
PIS - Plant Process Computer
RCW - Remote Configuration Workstation
SER - Sequential Event Recorder
TS - Technical Specifications
VCB - Ventilation Control Board

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