May 10, 2010

ORGANIZATION: AREVA NP, Inc.

PROJECT: U.S. EPR Design Certification

SUBJECT: SUMMARY OF AUDIT REGARDING PRIORITY ACTUATION AND CONTROL SYSTEM (PACS)

On August 5-6, 2009, the U.S. Nuclear Regulatory Commission (NRC) staff conducted an audit of information related to the U.S. EPR Priority Actuation and Control System (PACS) in support of Chapter 7 of the U.S. EPR Design Certification Application. The audit was conducted at the AREVA satellite office in Rockville, MD at 1700 Rockville Pike. An audit summary including participants, audit activities, and a summary of the exit meeting is provided in the enclosure.

Sincerely,

**/RA/**

Michael A. Canova, Project Manager
EPR Projects Branch
Division of New Reactor Licensing
Office of New Reactors

Docket No. 52-020

Enclosure:
As Stated

cc: See next page

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**ACCESSION NO.: ML092450527** **NRO-002**

| **OFFICE** | DNRL/NARP:PM | DNRL/NARP:LA | DE/ICE1:BC | DNRL/NARP:PM |
|---|---|---|---|---|
| **NAME** | MCanova | JMcLellan | TJackson | GTesfaye |
| **DATE** | 09/07/2009 | 12/02/2009 | 12/14/2009 | 05/10 /2010 |

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**REGULATORY AUDIT SUMMARY**
**AREVA Priority Actuation and Control Module**
**AREVA NP Office, Twinbrook Building**
**August 5 and 6, 2009**

## Purpose

The purpose of this regulatory audit was to cover the following items:

1. Review and evaluate the technical, procedural, and process information concerning the revised Priority Actuation and Control System (PACS) Module

2. Evaluate the methods by which AREVA NP will perform 100 percent combinational testing on the PACS module

3. Review and evaluate the technical, procedural and process information concerning the software testing tool that AREVA NP plans to utilize in order to perform verification and validation for the PACS module

4. Review the complete Protection System failure modes and effects analysis (FMEA) to identify any additional information that may need to be docketed

5. Review the U.S. EPR process system piping and instrumentation diagrams (P&IDs) to verify manual actions description in final safety analysis report

The intent of this audit was to gain further understanding of the technical and administrative processes that AREVA NP used to develop the design and operation of the PACS module and to verify single failure protection and use of manual actions in the Protection System. This regulatory audit verified proprietary information, as well as, identified information which requires future docketing to support the licensing basis of the PACS module and the Protection System.

## Regulatory Audit Bases

The regulatory bases for this audit include the following:

1. 10 CFR 50.55a (h), “Protection and Safety Systems.”

2. 10 CFR 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.”

3. 10 CFR 50, Appendix A, General Design Criteria 1, “Quality Standards and Records.”

4. 10 CFR 50, Appendix A, General Design Criteria 21, “Protection System Reliability and Testability.”

ENCLOSURE

## Regulatory Audit Scope/Methodology

The audit team's review focused on the operating capabilities and design characteristics of both the PACS module and the software testing tool and supporting documentation. The audit team evaluated the methodology by which AREVA NP will perform 100 percent combinational testing. In addition, the team verified details related to the use of manual actuations, data communication independence, and interface between plant components and the Protection System.

## Regulatory Audit Team

| NRC Employee | Office/Division/Branch | Role/Title |
|---|---|---|
| Wendell Morton | NRO/DE/ICE1 | Audit Team Leader / Electronics Engineer |
| Michael Canova | NRO/DNRL/NARP | Project Manager |
| Tung Truong | NRO/DE/ICE1 | Electronics Engineer |
| Calvin Cheung | NRO/DE/ICE1 | Electronics Engineer |
| Deanna Zhang | NRO/DE/ICE1 | Electronics Engineer |
| Bernard F. Dittman | NRR/ADES/DE/IECB | Electronics Engineer |

## AREVA NP Audit Support Personnel

Dennis Budzik

Chris Doyel

Hany Farag

Vic Frigonese

Christian Hessler

George Pannell

Shelby Small

**Regulatory Audit Scheduling**

Date of Audit: August 5-6, 2009

Location: AREVA NP Twinbrook Building
12300 Twinbrook Parkway
Rockville, MD 20852

Entrance Briefing Time: 1:00 PM, August 5, 2009

Audit Activities:

- Review and evaluate the design of the revised PACS Module and supporting documentation
- Evaluate AREVA NP methodology for 100 percent combinatorial testing
- Review and evaluation of the software development tool
- Evaluation of the complete FMEA for the Protection System
- Review U.S. EPR process system P&IDs to support verification of manual actuations and interface of the Protection System to plant components
- Independent reviewer evaluation of reference materials

Exit Briefing Time: 2:00 PM, August 6, 2009

**Information and Other Materials Necessary for the Regulatory Audit**

The audit team requested that AREVA NP make available the current revisions of the following documents in order to complete the audit:

- AV-42 Priority Actuation and Control Module Topical Report

- Available design documents for the programmable logic device testing tool. This would include AREVA NP providing available documentation on the planning, requirements, design, implementation, and verification and validation of the software tool.

- Available schematics, wiring diagrams, logic drawings and any other drawings that illustrate the internal construction of the new PACS module, as well as drawings that would allow the audit team members to trace any given logic input/output path through circuitry on the PACS module.

- A demonstration of the 100 percent combination testing method using a representative sample circuit. The sample circuit should be able to adequately model the type of circuit construction planned for the PACS, including the four classes of input signals.

- Available specifications on the hardware, firmware and/or software used to construct and program the PACS module.

- Any additional documentation and/or analyses that demonstrate compliance of the PACS (hardware, firmware and/or software) module and the software testing tool to applicable federal regulations and standards.

- The complete Protection System FMEA.

- U.S. EPR process system P&IDs to support verification of manual actuations and interface of the Protection System to the plant components.

The audit team also requested that AREVA NP provide at least two copies of each hard copy of drawings and other design documentation to facilitate the regulatory audit.

**Regulatory Audit Activities**

**1. Review and evaluate the design of the revised PACS Module and supporting documentation.**

*Review and evaluate the latest design configuration of the PACS module proposed by AREVA NP during their presentation to the NRC staff, dated April 29-30, 2009. Gain an understanding of the hardware, software, and architectural changes between the PACS topical report and the proposed PACS design.*

AREVA NP's Haney Farag, with support from Christian Hessler, made a presentation on the proposed PACS module based on an existing predecessor design.

The new PACS design is based on a predecessor design (the SPLM-PC10), which is a clocked module containing two programmable logic devices (PLDs), A and B. The PLDs do not share inputs, outputs, or resources such as the clock and power supply. For each PLD, the inputs are brought from a board connector and outputs are sent to the board connector (with signal conditioning). AREVA NP stated that operating history regarding the SPLM-PC10 is 102 module-years with zero failures. The oldest module is about 2.5 years. Mean-time-between-failure information should be provided as part of the information submittal on the PACS.

The new PACS scheme now includes design from the SPLM-PC10 PLD module and a separate communications module to take the place of the AV42 module. By using a separate communications module, AREVA NP plans to address the independence issue of the AV42 by having the non-safety communications module treated as an associated circuit.

AREVA NP plans to use the SPLM-PC10 module with similar logic programming for the U.S. EPR PACS. The logic on the SPLM-PC10 contained three logic functions that were implemented over the two PLDs. The current logic configuration contains two internal states. The current configuration does not provide access to these internal states. The testing program is intended to both perform and demonstrate 100 percent combinational testing for each PLD. The internal function testing of PLD A were discussed, the testing methodology for PLD B were postulated to be identical in implementation.

AREVA NP described the aspects of the new design and qualification process related to the hardware/software for the new module and the changes to the procedures required

to address 100 percent testing. They also described the smart sampling of test cases for manual verification versus the manual verification of all test cases as described in Digital Instrumentation and Control Interim Staff Guidance - 04, "Highly-Integrated Control Rooms – Communications Issues."

AREVA NP plans to provide the testing methodology and a technical report on the replacement priority module. These items will be docketed and reviewed at a future time.

Activity Conclusions and Findings

PACS will be addressed in "Methodology for 100% Combinatorial Testing of the U.S. EPR Priority Module Technical Report" which will be incorporated by reference in Chapter 7.

1a. Additional information on failure rates of the PC10 module is needed.

1b. The NRC staff will evaluate AREVA NP's proposal to perform manual verification on a select set of test cases versus manual verification of all test cases. Staff provided feedback on the proposal at the September 2-3, 2009 public meeting.

1c. PACS Testing Methodology

Page 7, "Some self monitoring features such as switching outputs off in case of overload, during start up of the module and in case of loss of power supply may also be implemented in the PLD (their processing in the PLD is referred to as processing of "infrastructure signals").

1. Are these self testing features a part of the PS's self testing features?
2. Are these features somehow internal to the PACS?
3. Are these features verified by Inspections, Tests, Analysis, and Acceptance Criteria (ITAAC) and Technical Specifications?

1d. In AREVA NP's submittal for the PACS design, development activities associated with requirements and design specifications should be described, including verification and validation activities to verify correct logic and timing.

**2. Evaluate AREVA NP methodology for 100 percent combinatorial testing.**

*Evaluate the acceptability of the testing plan and/or methodology used to perform testing. Observe the demonstration of the software testing methodology to ensure that 100 percent combination testing is accomplished and the results of the testing are clear to subsequent verification and validation personnel, as well as NRC auditors/inspectors.*

AREVA NP will be using an existing PLM module used from previous projects. To address the regulatory issues regarding Common Cause Failures and communications independence, AREVA NP will have two separate modules: one for communications (Profibus) and the other as a safety related PLD. The priority module is separated from the communications module.

The types of inputs to the priority module: Memorized actuation, non-memorized actuation signal and delayed actuation signal. Infrastructure Signals such as power supply status and output driver status were two infrastructure signals identified.

The test layout (groups of 60 test cases) is based on limitations of simple test machine/Excel test platform. The binary decomposition of the decimal value of the test case will be the input signal test vector. For the example presented, test cases are composed of 16 inputs plus two memorized states of internal latches. The total test cases with the 18 inputs will be $2^{18}$ or 262,144. For example, Test Case No. 22 will generate an input signal of "00 0000 0000 0001 0110." Signal verification occurs after stabilization (debounce is a function of input device characteristics).

To set the internal states, AREVA NP plans to use a sequence of inputs to place the logic in an expected state. The internal states can be observable from test points on the board, although it was not the case for the example provided. The NRC staff stated that the testing should provide the actual value of the internal states. AREVA NP will evaluate making the actual value of the internal states readable in the 100 percent combination testing.

If inputs have different debounce times, the output can change to an incorrect intermediate state while the various inputs are debouncing. This should be captured as a state change in the combinatorial test protocol.

AREVA NP proposed to only use the nominal state of the infrastructure signals in the 100 percent combinatorial testing, because change to the non-nominal state is the result of a single failure in a division and the failure is contained within the division. AREVA NP feels this meets the guidance of the draft NUREG on evaluating sufficient diversity.

Preset evaluation times in the Microsoft Excel test file ignore transitional states resulting from debounce times and delays to generate expected outputs. The test machine will simulate these intermediate states. Differences of this kind are expected and are not considered errors. Automatically flagged errors between expected and observed outputs will be manually re-run.

Activity Conclusions and Findings

2a. To address Interim Staff Guidance (ISG) 04, the internal states need to be monitored. Position 2.6 of the ISG identifies that, for internal states, all possible sequence steps of inputs need to be tested to verify the state or justify the exclusions.

2b. The outputs of the PLD should be observed and evaluated for the entire test case run. The staff understands that, due to debouncing circuits and signal processing within the PLD, there will be a transition period when new inputs are introduced. During this transition period, the output signals may not represent the correct value until the signal processing delays are completed. However, if the output signals are sent to other plant components, the effect of the transition period outputs should be evaluated as to how they impact those components. The staff understands that the majority of these transitional output signals are very short and would not impact most

electrical or mechanical components such as solenoids and relays. However, if the plant component is a digital system, it may be able to read and act on the transitional output signal. Identifying the transitional times in the test case data log would assist in performing the evaluation also.

2c. More detail should be added to the technical report to better define the self testing features of the PLD board. Also, details on which signals and what alarm functions from cabinets (that affect the PACS) are sent to the control room should be provided.

**3. Review and evaluation of the software development tool.**

*Review and evaluate the design and documentation of the software development tool against the criteria in the SRP Appendix 7.1-D and Regulatory Guide 1.152, Revision 2.*

The "Labview" implemented, automated test and evaluation platform for 100 percent combinational testing is a software tool classified by AREVA NP's quality assurance program, at the same level as the Simulation Validation Tool (SIVAT) software tool which is recommended for use in the Software Program Manual.

Activity Conclusions and Findings

3a. The pedigree of the software development tool, Labview, needs to be evaluated.

**4. Evaluation of the complete FMEA for the Protection System.**

*Compare the proprietary FMEA against the summary FMEA submitted as part of the U.S. EPR design certification application. Identify the additional information needed as part of the licensing basis. Verify the data communications design of the U.S. EPR.*

For the Remote Acquisition Unit (RAU), for detected failures, AREVA NP states there are two redundant RAUs per division to meet single failure criterion.

For an undetected spurious failure, the failure would cause a spurious actuation.

For an undetected blocking failure, the system is relying on the four redundant divisions to provide the two out of four voting on the Actuation Logic Unit (ALU).

Activity Conclusions and Findings

4a. Page 16 of the FMEA, second to last bullet states that a single Self Powered Neutron Detector (SPND) cannot fail due to a design basis event. AREVA NP states that they are all mounted together and in such a way that many would fail as opposed to one single failure. A request for additional information (RAI) will be written to ask for justification of this assumption and for more detail (Question 07.09-59)

4b. FMEA tables, Section 4, Pages 23-33, second to last column, "Effect on Protection System." The effects on reactor trip (RT) and engineered safety features (ESF) are written together under one section. A distinction between effects of failures on RT

and on ESF should be added. On the first part of the table, AREVA NP provides a clear distinction between RT and ESF by separating the two into individual columns. For clarity and consistency, the "Effect on Protection System," column should be split to show the individual effect on RT and ESF.

4c. For an undetected blocking failure, the system is relying on the four redundant divisions to provide the two out of four voting on the ALU. However, the FMEA does not address when a RAU is out of service for maintenance or testing and the redundant RAU suffers a single failure. The FMEA states that in this case, Technical Specifications define the limiting condition for operation. An RAI will be written to ask for justification of using Technical Specifications (TS) to address single failure criterion and for more detail.

4d. The non-detectable failure terminology used in the FMEA differs from that of Institute of Electrical and Electronics Engineers (IEEE) STD 603-1991. An RAI will be written on this (Question 07.02-30).

**5. Review U.S. EPR process system P&IDs to support verification of manual actuations and interface of the Protection System to plant components.**

*Use the U.S. EPR process system P&IDs to verify the implementation of manual actuations. Additionally, use the P&IDs to verify single failure protection and independence with regards to the interface between the Protection System and plant components.*

Activity Conclusions and Findings

5a. Evaluation of P&IDs during the audit revealed no issues. Further review is necessary to complete review of the P&IDs.

**6. Independent reviewer evaluation of provided documents.**

Documents provided by AREVA NP are listed in a later section.

Conclusions and findings from the audit as a result of the independent review of the provided documents are added in the appropriate section above.

**Provided Documents**

The Staff was provided the following documents for support of this fact-finding audit:

| Reference | Title | Ref | Rev | Date | Prepared by |
|---|---|---|---|---|---|
| 1 | Combinatory Testing for PACS-methodology and example | NLTC-G/2009/en/0047 | A | 7/15/2009 | Dr. Christian Hessler |
| 2 | Phase Model for the Development of Software Components for TELEPERM XS | TXS-1.1en | A | 8/1/2006 | R. Fehn |
| 3 | Configuration Management Plan for the TELEPERM XS System Platform | TXS 1.5en | C | 10/42005 | R. Wienke |
| 4 | SIVAT: TELEPERM XS Simulation Validation Test Tool (Topical Report) | ANP-10303NP | 0 | June 2009 | AREVA NP |
| 5 | Software Verification and Validation Plan (V&V Plan) | FAW No. TXS-1.6en | A | 2006-03-16 | Dr. B. Schnitzer |
| 6 | AV 42 Priority Actuation and Control Module | ANP-10273P | 0 | November 2006 | AREVA NP |
| 7 | Protection System Failure Modes and Effects Analysis for U.S. EPR FSAR | 51-9060041 | 002 | 6/26/08 | Paul Schmugge |
| 8 | Protection System Failure Modes and Effects Analysis for U.S. EPR FSAR | 51-9060041 | 003 | DRAFT | Duc Phan |

The AREVA NP topicals (Ref 4 and 6) were not utilized during this audit.

| Title | Serial number |
|---|---|
| Protection System Failure Modes and effects analysis for U.S. EPR FSAR | 51-9060041-002<br>51-9060041-003 (draft) |
| **P&IDs** | |
| **Reactor Coolant System** | |
| Reactor coolant loops | DCD-NPD-JEX-3001 |
| Reactor pressure vessel | DCD-NPD-JEX-3002 |
| Reactor coolant pressurizing & discharge system | DCD-NPD-JEX-3003 |
| Pressurizer safety relief valves | DCD-NPD-JEX-3004 |
| Pressurizer Instrumentation | DCD-NPD-JEX-3005 |
| Pressurizer heater details | DCD-NPD-JEX-3006 |
| Control rod drive mechanism details | DCD-NPD-JEX-3007 |
| Steam Generator loop 1 | DCD-NPD-JEX-3101 |

| Title | Serial number |
|---|---|
| Primary coolant pump loop 1 (pump motor) | DCD-NPD-JEX-3103 |
| Steam generator loop 2 | DCD-NPD-JEX-3201 |
| Primary coolant pump loop 2 (pump motor) | DCD-NPD-JEX-3203 |
| Steam generator loop 3 | DCD-NPD-JEX-3301 |
| Reactor coolant pump loop 3 (pump body) | DCD-NPD-JEX-3302 |
| Primary coolant pump loop 3 (pump motor) | DCD-NPD-JEX-3303 |
| Steam generator loop 4 | DCD-NPD-JEX-3401 |
| Primary coolant pump loop 4 | DCD-NPD-JEX-3403 |
| **Emergency Feedwater System** | |
| Supply, discharge and drain headers | DCD-NPD-LAR-3001 |
| Storage pool-train 1 | DCD-NPD-LAR-3010 |
| Pump and piping train | DCD-NPD-LAR-3011 |
| Pump and motor train 1 | DCD-NPD-LAR-3010 |
| **Chemical Volume and Control System** | |
| Letdown function-1 | DCD-NPD-KBA-3001 |
| Letdown function-2 | DCD-NPD-KBA-3002 |
| Volume control tank | DCD-NPD-KBA-3003 |
| Charging function | DCD-NPD-KBA-3004 |
| Charging function 2 | DCD-NPD-KBA-3005 |
| HP charging pump KBA31 AP001 | DCD-NPD-KBA-3006 |
| HP charging pump KBA32 AP001 | DCD-NPD-KBA-3007 |
| Chemical control system | DCD-NPD-KBD-3001 |
| ROP seal 1 leakoff | DCD-NPD-JEW-3002 |
| **Safety Injection System and Residual Heat Removal System** | |
| Safety injection system, residual heat removal system reactor building, train1 | DCD-NPD-JNX-3102 |
| Safety injection system accumulator, train1 | DCD-NPD-JNX-3103 |

| Title | Serial number |
|---|---|
| Emergency feedwater section - supply, discharge and drain headers | DCD-NPD-LAR-3001 |
| Emergency feedwater section storage pool,-train1 | DCD-NPD-LAR-3010 |
| Emergency feedwater section pump and piping,-train1 | DCD-NPD-LAR-301 |
| **Main Feedwater System** | |
| Feedwater piping system (LAB), Feedwater pump 1 of 3 | DCD-MPD-LAB-3002 |
| Feedwater piping system (LAB), Feedwater pump 2 of 3 | DCD-MPD-LAB-3003 |
| Feedwater piping system (LAB), Feedwater pump 3 of 3 | DCD-MPD-LAB-3004 |
| Startup/shutdown feedwater piping system (LAH) | DCD-MPD-LAB-3005 |
| Startup/shutdown feedwater piping systems (LAH) from discharge isolation valves to HP feedwater heaters | DCD-MPD-LAB-3006 |
| Feedwater piping system (LAB) HP feedwater heaters 1 of 2 | DCD-MPD-LAB-3007 |
| Feedwater piping system (LAB) HP feedwater heaters 2 of 2 | DCD-MPD-LAB-3008 |
| Startup/shutdown feedwater piping system (LAH) from HP feedwater heaters to pipe bridge | DCD-MPD-LAB-3009 |
| Startup/shutdown feedwater piping system (LAH) from pipe bridge to steam generator 1 | DCD-MPD-LAB-3010 |
| Startup/shutdown feedwater piping system (LAH) from pipe bridge to steam generator 2 | DCD-MPD-LAB-3011 |
| Startup/shutdown feedwater piping system (LAH) from pipe bridge to steam generator 3 | DCD-MPD-LAB-3012 |
| Startup/shutdown feedwater piping system (LAH) from pipe bridge to steam generator 4 | DCD-MPD-LAB-3013 |
| **Main Steam System** | |
| Lines 2 and 3 from pipe bridge to HP turbine/turbine bypass | DCD-MPD-LBA-3006 |
| **Title** | **Serial number** |
| Lines 1 and 4 from pipe bridge to HP turbine/turbine bypass | DCD-MPD-LBA-3007 |
| Turbine bypass | DCD-MPD-LBA-3008 |
| Safety grade part from steam generator 1 to pipe bridge | DCD-MPD-LBA-3101 |

**Exit Briefing and Conclusion**

The following areas of interest were identified during the audit (Parking Lot Issues) as requiring additional clarification:

1. Regarding 100 percent combinational testing, is it acceptable to utilize the 16 input approach (1 PLD) vs. the two PLD (32 inputs) approach to meet the intent of the ISG?

2. If two inputs are offset in time due to debouncing, what are the criteria for evaluating the validity of the output?

3. How are the internal states verified and can they be verified?

4. What is a smart sample, how is it selected and what is its basis?

5. The Pedigree of the base commercial software tool (Labview) needs to be evaluated.

With the exception of Item 3, the Parking Lot Issues are left open and require additional action from both NRC and AREVA NP. They will be further discussed at the September 2-3, 2009, public meeting. Item 3, regarding internal states, was addressed by AREVA NP. Internal states are not specifically tested and cannot be explicitly set to a particular value. A sequence of inputs based on the known logic design is required to force a specific internal state.

Additionally, audit activities conclusions and findings are discussed in the appropriate section above.

**Regulatory References**


1. IEEE Standard 603-1991, “Criteria for Safety Systems for Nuclear Power Generating Stations.”

2. IEEE Standard 384-1992, “Criteria for Independence of Class 1E Equipment and Circuits.”

3. Regulatory Guide 1.152, “Criteria for Digital Computers in Safety Systems of Nuclear Power Plants,” Revision 2.

4. IEEE Standard 7-4.3.2-2003, “Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations.”

5. ISG-04, “Highly-Integrated Control Rooms – Communications Issues.”

6. BTP 7-14, “Guidance on Software Reviews for Digital-Based Instrumentation and Control Systems.”

7. Regulatory Guide 1.22, “Periodic Testing of Protection System Actuation Functions.”

8. NUREG 0800, “Standard Review Plan for Instrumentation and Control Systems.”