Criteria 1.2.1
I&C and Inherent Characteristics

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Initial Pre-application Meeting

1. INPRO Criteria 1.2.1

2. APR1400 I&C Design Characteristics

3. INPRO Evaluation
   • EP 1.2.1.1 Continuous Monitoring of Plant Health
   • EP 1.2.1.2 Dynamic Plant Analysis

4. Summary
## INPRO Criteria 1.2.1 I&C and Inherent Characteristics

### User Requirements and Criteria

**Basic Principle BP1 (Defense in Depth):**  
*Installations of an Innovative Nuclear Energy System shall incorporate enhanced defence-in-depth as a part of their fundamental safety approach and ensure that the levels of protection in defence-in-depth shall be more independent from each other than in existing installations.*

<table>
<thead>
<tr>
<th>User requirements (UR)</th>
<th>Criteria (CR)</th>
</tr>
</thead>
</table>
| **UR1.2 (Detection and interception):**  
*Installations of an INS should detect and intercept deviations from normal operational states in order to prevent anticipated operational occurrences from escalating to accident conditions.* | **Indicators (IN)***  
CR1.2.1 I&C and inherent characteristics  
**IN1.2.1: Capability of control and instrumentation system and/or inherent characteristics to detect and intercept and/or compensate deviations from normal operational states.* | **Acceptance Limits (AL)***  
CR1.2.1: Key system variables relevant to safety (e.g., flow, pressure, temperature, radiation levels) do not exceed limits acceptable for continued operation (no event reporting necessary). |
## INPRO Criteria 1.2.1 I&C and Inherent Characteristics

### Defense-in-Depth

<table>
<thead>
<tr>
<th>DID Level</th>
<th>INSAG Objectives</th>
<th>Innovation Direction (INPRO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prevention of abnormal occurrences and accidents</td>
<td>Enhance prevention by increased emphasis on inherently safe design characteristics and passive safety features, and by further reducing human actions in the routine operation of the plant.</td>
</tr>
<tr>
<td>2</td>
<td>Control of abnormal operation and detection of failures</td>
<td>Give priority to advanced control and monitoring systems with enhanced reliability, intelligence and the ability to anticipate and compensate abnormal transients.</td>
</tr>
<tr>
<td>3</td>
<td>Control of accidents within the design basis</td>
<td>Achieve fundamental safety functions by optimized combination of active &amp; passive design Features.</td>
</tr>
<tr>
<td>4</td>
<td>Control of severe plant conditions</td>
<td>Increase reliability and capability of systems to control and monitor complex accident sequences; decrease expected frequency of severe plant Conditions.</td>
</tr>
<tr>
<td>5</td>
<td>Mitigation of radiological consequences</td>
<td>Avoid the necessity for evacuation or relocation measures outside the plant site.</td>
</tr>
</tbody>
</table>
Evaluation Parameters and Acceptability

- **Evaluation parameter EP1.2.1.1: Continuous monitoring of the plant health**
  - *Acceptability of EP1.2.1.1*: Evidence is available to the INPRO assessor that the INS design includes systems for continuous monitoring of plant health and computerized aids for the operators.

- **Evaluation parameter EP1.2.1.2: dynamic plant analysis**
  - *Acceptability of EP1.2.1.2*: Evidence is available to the INPRO assessor that a deterministic and probabilistic plant analysis has been performed for the INS and the results confirm that key system variables relevant to safety do not exceed limits acceptable for continued operation and do not result in any short term consequences affecting normal operation.
# APR1400 I&C Design Characteristics

## I&C Platform History

<table>
<thead>
<tr>
<th>Plants</th>
<th>Reactor Trip System</th>
<th>ESFAS Systems</th>
<th>Protection Process</th>
<th>NSSS Control</th>
<th>PCS</th>
<th>TBN Control</th>
<th>Main Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kori 1</td>
<td>Relay Logic (WEC)</td>
<td>Relay Logic (WEC)</td>
<td>Foxboro H-line</td>
<td>Foxboro H-line</td>
<td>Foxboro H-line</td>
<td>DCS</td>
<td>Conventional</td>
</tr>
<tr>
<td>Kori 1 (Upgrade)</td>
<td>Relay Logic (WEC)</td>
<td>Relay Logic (WEC)</td>
<td>Spec200 Spec200m (Foxboro)</td>
<td>Spec200 Spec200m (Foxboro)</td>
<td>Spec200 Spec200m (Foxboro)</td>
<td>DCS</td>
<td>Conventional</td>
</tr>
<tr>
<td>Kori 2,3,4 YGN 1,2</td>
<td>SSPS Relay Logic (WEC)</td>
<td>SSPS Relay Logic (WEC)</td>
<td>7300 Analog</td>
<td>7300 Analog</td>
<td>7300 Analog</td>
<td>Mark V (GE)</td>
<td>Conventional</td>
</tr>
<tr>
<td>YGN 3,4</td>
<td>Relay Logic (ABB-CE)</td>
<td>Relay Logic (ABB-CE)</td>
<td>Spec200 (Foxboro)</td>
<td>Spec200 Spec200m (Foxboro)</td>
<td>ILS (Forney)</td>
<td>Mark V (GE)</td>
<td>Conventional</td>
</tr>
<tr>
<td>Ulchin 3,4 YGN 5,6</td>
<td>Relay Logic (ABB-CE)</td>
<td>Relay Logic (ABB-CE)</td>
<td>Spec200 (Foxboro)</td>
<td>Spec200m/PLC (Foxboro)(Omron)</td>
<td>PCS (Eaton)</td>
<td>Mark V (GE)</td>
<td>Hybrid</td>
</tr>
<tr>
<td>Wolsong 1,2,3,4</td>
<td>Relay Logic (AECL)</td>
<td>Relay Logic (AECL)</td>
<td>Analog/PDC (AECL)</td>
<td>DCC X/Y (Computers Control)</td>
<td>Analog/Relay (AECL)</td>
<td>Mark V (GE)</td>
<td>Hybrid</td>
</tr>
<tr>
<td>Ulchin 5,6</td>
<td>PLC (WEC)</td>
<td>PLC (WEC)</td>
<td>Spec200 (Foxboro)</td>
<td>PLC (Omron)</td>
<td>AFS100/ECS1200 (HFC)</td>
<td>Mark V (GE)</td>
<td>Hybrid</td>
</tr>
<tr>
<td>Shin Kori 1,2 Shin Wolsong 1,2</td>
<td>PLC (WEC)</td>
<td>PLC (WEC)</td>
<td>Spec200 (Foxboro)</td>
<td>PLC (Omron)</td>
<td>HFC6000 (HFC)</td>
<td>Mark VI (GE)</td>
<td>Hybrid</td>
</tr>
<tr>
<td>Shin Kori 3,4 (APR1400)</td>
<td>PLC (WEC)</td>
<td>PLC (WEC)</td>
<td>PLC (Omron)</td>
<td>DCS (WE)</td>
<td>DCS (WE)</td>
<td>Mark VI (GE)</td>
<td>Compact Workstation</td>
</tr>
<tr>
<td>Shin Ulchin 1,2 (APR1400)</td>
<td>PLC (DOOSAN)</td>
<td>PLC (DOOSAN)</td>
<td>PLC (DOOSAN)</td>
<td>DCS (DOOSAN)</td>
<td>DCS (DOOSAN)</td>
<td>Mark VI (GE)</td>
<td>Compact Workstation</td>
</tr>
</tbody>
</table>
APR1400 I&C Design Characteristics

Main Control Room

- Large Display Panel
- Safety Console
- Compact Operator Console

**APR1400 I&C Design Characteristics**

**I&C System Overview of APR1400**

- Microprocessor based digital I&C technology
  - common PLC platform for safety I&C
  - common DCS platform for non-safety I&C
- Four (4) channel redundancy for safety I&C
  - installed in separate channelized I&C equipment room.
- Multiplexed I/O and redundant communication network
  - from field areas to I&C equipment rooms and MCR
- Diverse Actuation System to cope with the CMF of safety I&C
- Complete electrical, physical and communication isolation
  - between redundant safety channels
  - between safety system and non-safety system
**APR1400 I&C Design Characteristics**

**I&C System Overview of APR1400**

- **Protection System**
  - Plant Protection System (PPS)
  - Engineered Safety Features-Component Control System (ESF-CCS)
  - Core Protection Calculator System (CPCS)
  - Auxiliary Process Cabinet – Safety (APC-S)

- **Diverse Actuation System**
  - Diverse Protection System (DPS)
  - Diverse Indication System (DIS)
  - Diverse Manual ESF Actuation Control Switches (DMA switches)
Control & Monitoring System
- Power Control System (PCS)
- NSSS Process Control System (NPCS)
- Process-Component Control System (P-CCS)
- Qualified Indication and Alarm System (QIAS) – PAMI
- Qualified Indication and Alarm System (QIAS) – Non-safety
- Neutron Flux Monitoring System (ENFMS / FIDAS)
- NSSS Integrity Monitoring System (ALMS / IVMS / LPMS / RCPVMS)
- T/G Control & Monitoring System
APR1400 I&C Design Characteristics

NSSS Integrity Monitoring System (NIMS)

SKN3&4 NIMS Network Architecture

- FPD with Touch Pad & Keyboard
- KV Switch
- RCPVMS-AU Computer (28 Inputs)
- ALMS-AU Computer (13 Inputs)
- LPMS-AU Computer (16 Inputs)
- IVMS-AU Computer (12 Inputs)
- FPD with Touch Pad & Keyboard
- KV Switch
- Ethernet Hub
- Audio Streaming Device
- Ethernet Router
- NTP Time Server
- Printer
- Plant LAN (WAN)
- NIMS Operating Station (NOS) Computer
- Real-Time NIMS Alarm Status Display
- Information Processing System (IPS)
- NIMS Status & Alarms
# APR1400 I&C Design Characteristics

## NSSS Integrity Monitoring System (NIMS)

<table>
<thead>
<tr>
<th>Items</th>
<th>OPR1000</th>
<th>APR1400</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H/W</strong></td>
<td><strong>PC:</strong> Alarm Unit, LPAP, DAD&lt;br&gt;<strong>AlphaServer:</strong> LPMS-AC&lt;br&gt;<strong>STD Bus:</strong> LPMS-AU</td>
<td><strong>Industrial PC</strong>&lt;br&gt;(All Alarm Unit &amp; NOS)</td>
</tr>
<tr>
<td><strong>OS &amp; S/W</strong></td>
<td><strong>MS-DOS:</strong> LPMS-AU&lt;br&gt;<strong>Win-98:</strong> LPAP&lt;br&gt;<strong>Win-XP:</strong> RCPVMS/ALMS-AU, NOS/IVMS Computer&lt;br&gt;<strong>OpenVMS:</strong> LPMS-AC</td>
<td><strong>OS:</strong> Windows&lt;br&gt;<strong>Application:</strong> NI LabVIEW™ based S/W</td>
</tr>
<tr>
<td><strong>Remote Control</strong></td>
<td>All subsystem excluding LPMS</td>
<td>All subsystems</td>
</tr>
<tr>
<td><strong>Cabinet</strong></td>
<td><strong>2 Cabinets:</strong> AUC &amp; ACC&lt;br&gt;■ AUC : MCR&lt;br&gt;■ ACC : Computer Room</td>
<td><strong>1 Cabinet:</strong> AUC (I&amp;C E.R)&lt;br&gt;<strong>1 Console:</strong> ACC (Computer Room)</td>
</tr>
</tbody>
</table>
APR1400 I&C Design Characteristics

Plant Control System

Overview of NSSS Control System

RRS
- Tavg
- TLI
- \( \phi \)

CEDMCS
RPCS

PPCS
- Pressure
- Level

CEDM

PLCS
- Level
- Tavg

PZR

SBCS
- Steam Flow
- Head Press
- PZR Press

TCS

TURBINE

CONDENSER

ELECTRIC OUTPUT

SPEED

ATBV

TCV

CTBV

FWCS
- S/G Flow
- S/G Level
- Feed Flow

S/G

MFWP

Reactor

RCP

CV

LV

Tavg : RCS Temp.
TLI : Turbine Power
\( \phi \) : Reactor Power
APR1400 I&C Design Characteristics

Nuclear Plant Analyzer (NPA)

- Win-NPA (Windows-based Nuclear Plant Analyzer)
  - Windows based desk-top engineering simulator
  - Engineering/training tool for operators/designers

- Characteristics
  - Real-time, best-estimate simulation for NPP
  - Accurate, easy-to-use & easy-to-understand analysis tool
  - Dedicated tools for development & customization
  - Supports external interfaces (DB, I&C devices)
APR1400 I&C Design Characteristics

Nuclear Plant Analyzer (NPA)

- SIS CVCS AFW
- Component Models
- 3D Reactor Core Model
- NSSS TH Model
- BOP Model
- Generic Control System Model

- RCP
- Pressurizer
- Steam Generator
- Valves
- Pumps
- Heat Exchangers

- Control Rods
- Doppler Effect
- MTC
- Boron
- Xenon
- Samarium
- PPS, RRS, PLCS
- PPCS, FWCS, SBCS
- RPCS, TCS
- Steam Line
- Turbine
- Condenser
- Feed Train
APR1400 I&C Design Characteristics

Nuclear Plant Analyzer (NPA)
APR1400 I&C Design Characteristics

Nuclear Plant Analyzer (NPA)

Secondary Mimic
APR1400 I&C Design Characteristics

Nuclear Plant Analyzer (NPA)

Plots
INPRO Evaluation

Continuous Monitoring of Plant Health

- Evaluation parameter EP1.2.1.1: Continuous monitoring of the plant health
  - Acceptability of EP1.2.1.1: Evidence is available to the INPRO assessor that the INS design includes systems for continuous monitoring of plant health and computerized aids for the operators.

- APR1400 Design has advanced Plant Health Monitoring Capability over OPR1000:
  - Full computerized I&C System
  - Improved NSSS Integrity Monitoring System
  - Other computerized plant monitoring systems are available
INPRO Evaluation

Dynamic Plant Analysis

- Evaluation parameter EP1.2.1.2: dynamic plant analysis
  - **Acceptability of EP1.2.1.2**: Evidence is available to the INPRO assessor that a deterministic and probabilistic plant analysis has been performed for the INS and the results confirm that key system variables relevant to safety do not exceed limits acceptable for continued operation and do not result in any short term consequences affecting normal operation.

- **APR1400 utilized advanced Nuclear Plant Analyzer (NPA) for dynamic plant analysis**
  - Real-time, best-estimate simulation for NPP transients under normal, abnormal and accident conditions
  - Accurately model plant control systems to simulate abnormal operation conditions
INPRO Evaluation

Dynamic Plant Analysis

Load Rejection to House Load

- SG 1 NR Level, %
- EFVCV1 Position Demand, %
- FW1 Flow DP, %
- SG 1 Steam Flow DP, %
Dynamic Plant Analysis

Loss of a main Feedwater Pump

- SG 1 NR Level, %
- EFNCV 1 Position Demand, %
- FW1 Flow DP, %
- SG 1 Steam Flow DP, %
Summary

- APR1400 I&C utilize full-digital technology and is designed to detect and intercept deviations from normal operational states.

- Integrated plant monitoring system and control systems prevent unnecessary safety system actuations.

- Dynamic simulation tool was utilized to verify APR1400 design capabilities.
  - For a full loss of load and loss of a main feedwater pump events, all safety related variables can be controlled within the limit allowing a continued operation with event reporting.

- Therefore, APR1400 Design satisfies Criteria 1.2.1 I&C and Inherent Characteristics.