



Report
of the
EXPERT MISSION
to
review the Station Blackout Event that happened at
Kori 1 NPP on 9 February 2012
Republic of Korea

4 – 11 June 2012

DIVISION OF NUCLEAR INSTALLATION SAFETY
OPERATIONAL SAFETY REVIEW MISSION
IAEA-NSNI/Expert mission

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1. INTRODUCTION AND MAIN CONCLUSIONS

1.1 Introduction and Event Summary

Introduction

A preparatory meeting was conducted at the IAEA on 11 April 2012 with the representatives of Korea Hydro & Nuclear Power Co., Ltd (KHNP) to discuss the scope, schedule and necessary preparations for the EM.

The IAEA assembled the team at the request of KHNP to conduct this expert mission using the methodology of Operational Safety Review (OSART) to perform the review from 4 to 11 June 2012. The eight member team was made up of experts from Belgium, France, Sweden, United Kingdom and IAEA.

Before visiting the plant, the team studied the advance information package, including the detailed description of the event, prepared by Kori 1 NPP. The team conducted the analysis of the event an in-depth review of those aspects of the safe operation of the Kori 1 NPP which are relevant to the station blackout event. The review covered the areas of Management, Organization and Administration, Safety Culture, Operations, Maintenance, Electrical Systems and Operating Experience.

Information on the following subjects not belonging to the scope of the expert mission was provided to the team in the advance information package, to help to better understand the context of the issues influencing the public opinion concerning Kori 1 NPP: reactor pressure vessel integrity, life time evaluation, ageing management program, component replacement and safety reinforcement based on lessons learnt from the Fukushima Accident.

The conclusions of the expert mission team were based on comparing the performance of KHNP and Kori 1 NPP with relevant parts of the IAEA Safety Standards and other applicable IAEA publications listed in the references.

Event summary

On February 9, 2012, during the 29- th refueling outage of Kori 1 NPP, loss of off-site power (LOOP) occurred and emergency diesel generator (EDG) 'B' failed to start while EDG 'A' was out of service for scheduled maintenance, resulting in a station blackout (SBO).

At the time of the event the reactor vessel head was removed and refueling cavity was flooded with borated water. The fuel transfer from reactor pressure vessel to spent fuel pool was under preparation. Shutdown cooling was being provided by the residual heat removal (RHR) pump 'B'. The RHR pump 'A' was under maintenance. While the 4.16kV safety bus 'A' was not available as it was under maintenance, 4.16kV safety bus 'B' was energized from 345kV off-site power through the unit auxiliary transformer (UAT) 'B'. The station auxiliary transformer (SAT) 'B' and EDG 'A' were out of service for maintenance. The maintenance for SAT 'A' was completed but the breaker was left open and the transformer was not returned to

operation at that time. So the available power sources, at that time, were one 345kV off-site power connected to the UAT 'B', EDG 'B', and AAC DG which met the required power source configuration for the refueling modes of the plant technical specification chapter 3.8.2.

The LOOP was caused by human error during the protective relay test of the main generator, and the subsequent SBO was due to the startup failure of the 'EDG B' caused by functional degradation, i.e the mechanical damage on the solenoid valve of the startup air system of the EDG B.

The SBO led the loss of RCS shutdown cooling and spent fuel pool cooling. In response to the SBO, the MCR operators restored the electrical power by connecting to SAT 'A' rather than to AAC DG (in stand-by state and in arrangement with Kori Unit-4), and subsequently restored the power supply to the RHR pump 'B' in accordance with the procedure by establishing cross-tie of 480V bus 'A' with 480 bus 'B' because RHR 'A' was under maintenance.

The shutdown cooling was lost for 19 minutes. As a result of the event, the reactor coolant maximum temperature in the hot leg increased from 37 C to 58. 3 C (approximately 21.3 C increase) and the temperature of spent fuel pool was increased slightly from 21C to 21.5 C. No fuel damage was identified based on RCS I-131 activity analysis and thermal hydraulic audit calculation by regulatory investigation team.

There was no adverse effect on the plant safety as a result of this event, no radiation exposure to the workers, and no release of radioactive materials to the environment. However, inconsistent with the requirements, the Kori 1 NPP did not report the SBO event to NSSC in a timely manner and did not declare the "alert" status of the event in accordance with the plant emergency plan. The Kori 1 NPP reported this event to NSSC on 12 March 2012.

NSSC ordered the reactor shutdown, made the event public, and dispatched immediately the regulatory special inspection team to investigate the event.

1.2 Main Conclusions

The Expert Mission (EM) team confirmed that Nuclear Safety and Security Commission has completed its interim investigation and continues to perform additional investigation and technical review. Corrective actions were determined for Kori 1 NPP based on the interim investigation concerning reinforcing safety culture, Emergency Diesel Generator (EDG) reliability, configuration control and risk management during refueling outage, test and maintenance procedures and emergency action level declaration. The EM team confirmed that part of the corrective actions are already completed, implementation of others are in progress. The management and staff of Kori 1 NPP is committed and working hard to complete all improvements.

The root cause analysis of the event by Kori 1 NPP is still in progress. It will lead to further corrective actions in safety culture, process and design enhancements.

The EM team performed its own analysis of the station blackout event that happened during generator protection test, the non-reporting of this event, the violation of the plant Technical Specifications by not immediately starting to take action to restore EDG to operable conditions and by starting of fuel movement with no operable EDGs next day. As a result of

this analysis the team identified additional contributing causes and corrective actions for Kori 1 NPP.

Some examples of important contributing causes are:

- The safety culture at Kori 1 NPP was unable to counter neither the errors committed in the station blackout event, nor the subsequent leadership failures in communication and reporting. The Kori 1 NPP safety culture needs to support leadership in decision making and develop stronger defenses when facing unexpected or difficult situations;
- Human factor: the disregard of instruction associated with overconfidence of contractor's worker during generator protection test;
- Kori 1 plant manager and other staff in the control room decided not to report SBO. The plant manager opted to hide this event due to heavy feelings of a burden to preempt public critics and a fear of worsening the plant's credibility. In light of the prevailing high respect for authority of supervisor the staff involved were unwilling to disagree with plant manager, although several elements of safety policy and administrative procedures of the plant were violated;
- Rescheduling outage work (generator protection system test was started earlier than the original schedule, maintenance of station auxiliary transformer A was started although station auxiliary transformer B was not returned to operation). The approval and risk assessment for this unusual lineup was inadequate in that the potential consequences were not considered;
- Kori 1 NPP internal oversight failed to reveal the station blackout event.

The EM team made recommendations to address these contributing factors.

In addition the team also made some recommendations and suggestions concerning the plant's practice of reporting events, event analysis, independent oversight, main control room activities and the workmanship of maintenance staff and contractors. Implementation of the IAEA recommendations and suggestions will considerably improve safety of Kori 1 NPP.

Kori 1 NPP management stated their commitment to address all the areas identified for improvement.

The EM team has identified good plant programmes, for example:

- The plant walk downs confirmed good material condition of equipment including those that caused the station blackout;
- Kori 1 NPP has implemented several equipment replacement and upgrade for successful continued operation;
- The IAEA Safe Long Term Operation mission in 2007 recognized that the plant approaches for the continued operation are in line with international practices, since then the plant has been actively implementing its ageing management programme;
- The plant has analysed the lessons of the Fukushima accident and implementation of broad scope of safety improvements is already in progress.

1. 3 Basic Plant Information

1.3.1 Description of Kori site

There are 5 nuclear units in operation (Kori unit 1,2,3,4 and Shin-Kori unit 1) and 3 units are under construction (Shin-Kori 2, 3, 4).

Kori Unit 1 was the first nuclear power plant in Republic of Korea.

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1.3.2. Kori 1 NPP history

- May 1972: Construction Permit (CP) and Operating License (OL) issued
- Jun 1977: Initial Criticality
- Jun 1977: First grid synchronization
- Apr 1978: Commercial operation
- Jun 1997: Rotor of LP turbine replaced
- Sep 1998: SGs and process control/protection system replaced
- Dec 2001: ATWS mitigation components installed
- Oct 2001: Main transformer replaced
- May 2005: Main generator and exciter system replaced
- Dec 2007: License renewal for continued operation till 2017

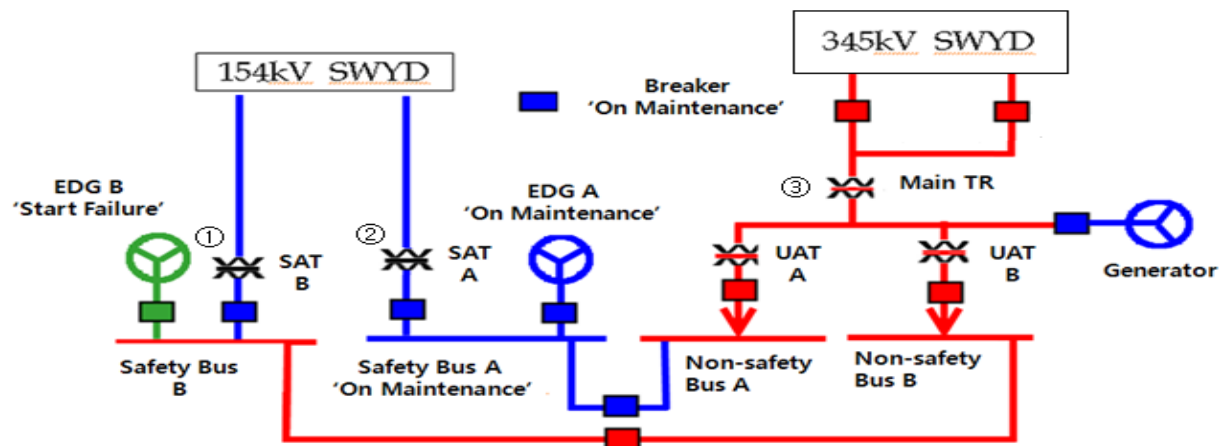
The first ever IAEA Operational Safety Review Team (OSART) mission was conducted at Kori NPP in 1983.

The IAEA Safe Long Term Operation Mission (SALTO) was conducted at Kori 1 NPP in July 2007.

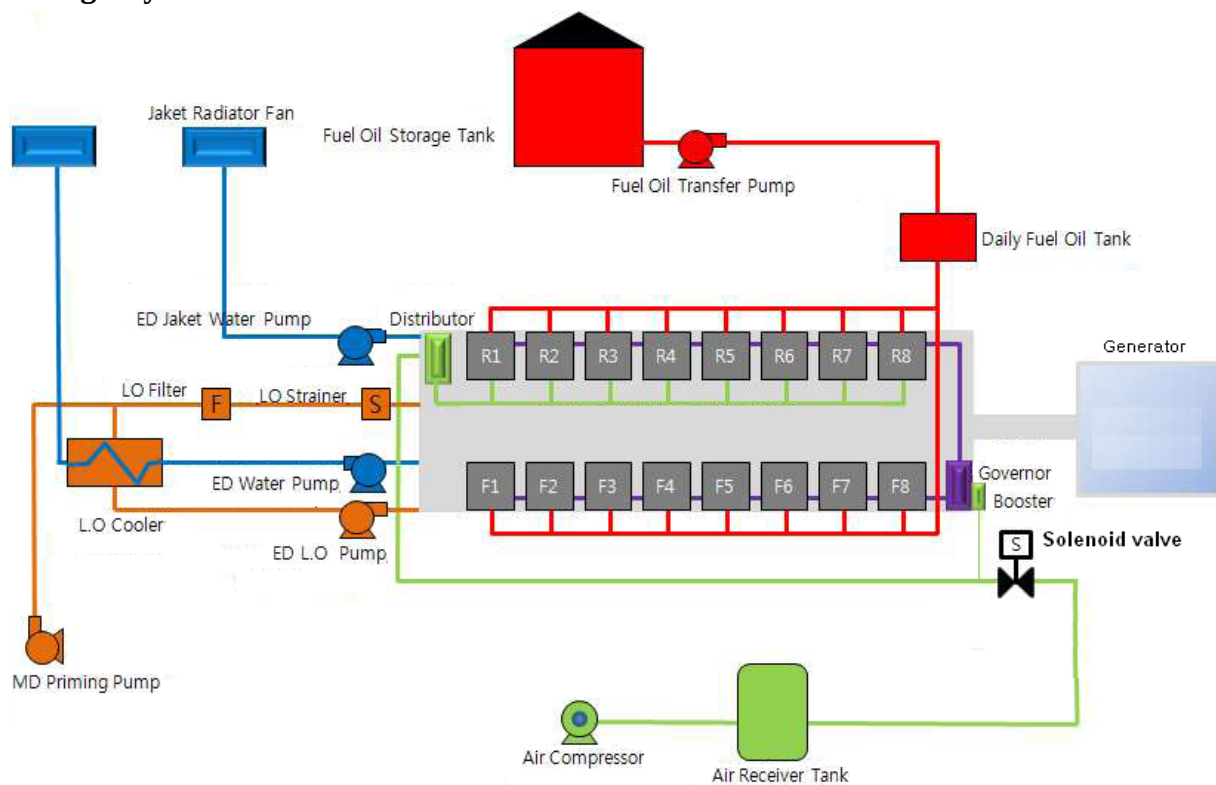
1.3.3 Key parameters

Reactor type	PWR, two loops
Net electrical output (MWe)	610 MWe
Thermal power output (MWth)	1,723 MWth
Condenser cooling water source	Sea Water
Site design earthquake Earthq.)	0.2 g (Safe Shutdown)
Number of off-site power supplies	2
Voltage of off-site power supplies	154kV/345kV
Number of high-voltage buses for on-site power supplies	2
Number of diesel generators, voltage, capacity	2 / 4.16kV/2,920kW
Other on-site backup power supplies	1 AAC D/G /4.16kV/5,500kW
Emergency Core Cooling	
a. High pressure injection	
Number of trains	2
Number and type of pumps	2 Electrical, Centrifugal
b. Low pressure injection (RHR)	
Number of trains	2
Number and type of pumps	2 Electrical, Centrifugal

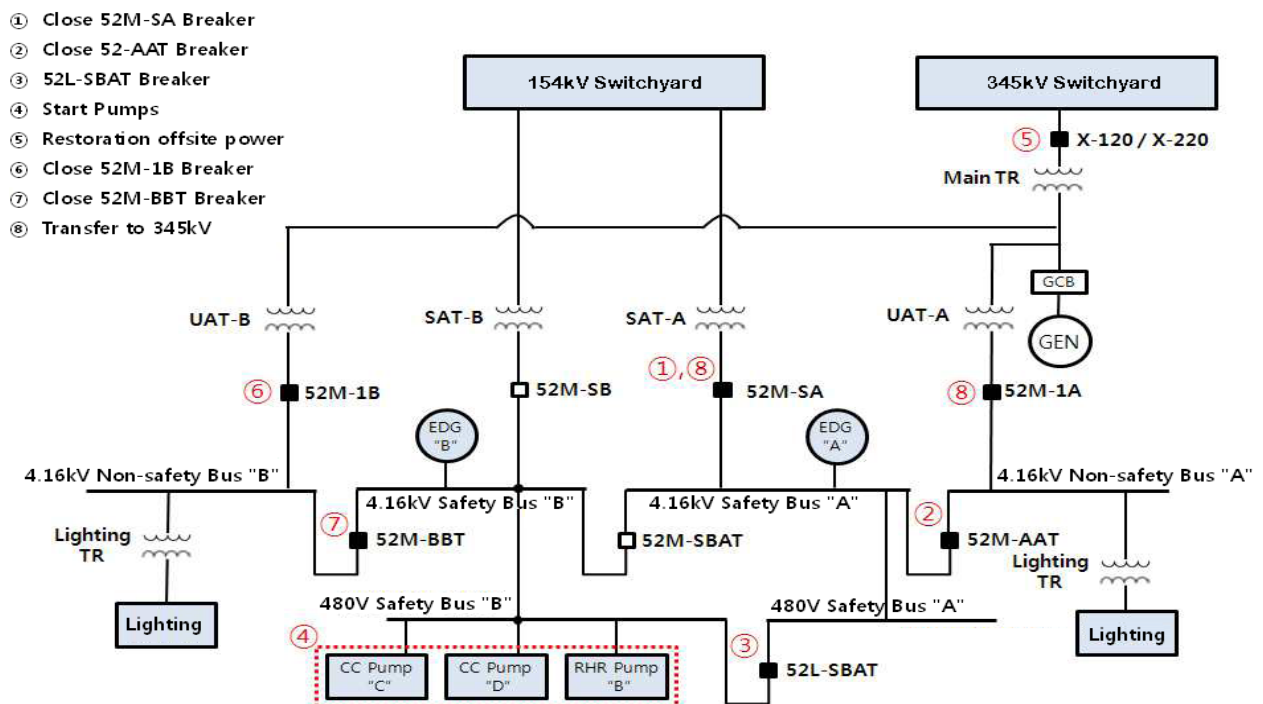
Electrical Scheme



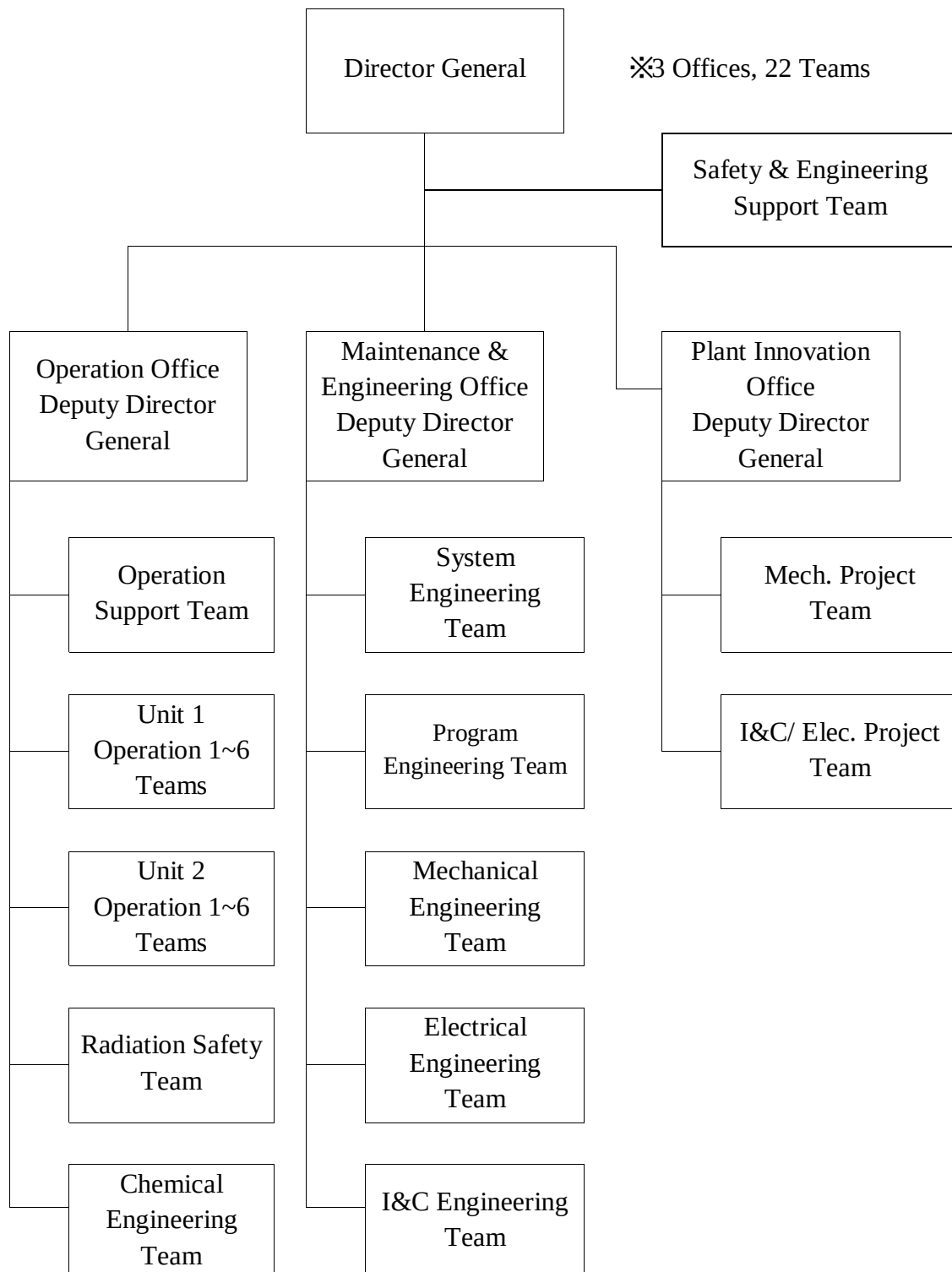
Emergency Diesel Generator



Restoration of Power Supply



1.3.4 Organization and Structure of Kori 1 NPP



2. EVENT ANALYSIS

2.1 Sequence of Events

<u>Feb. 4 2012</u>	
10:23	Control shutdown Reactor for refueling & overhaul
13:00	Originally planned start of SAT 'A' overhaul
<u>Feb. 5 2012</u>	Started maintenance for EDG 'A' and SAT 'A'
<u>Feb. 7 2012</u>	
13:00	Originally planned end of SAT 'A' overhaul
<u>Feb. 8 2012</u>	Held pre-job briefing related to the relay test of generator
	- Finished SAT 'A' maintenance, but incoming breaker left open
	- Started SAT 'B' maintenance
09:00	Originally planned start of SAT 'B' overhaul
<u>Feb. 9 2012</u>	
19:30	Started protective relay test of GCB (Generator Circuit Breaker)
20:34:30	Occurred LOOP, low voltage on the safety Bus
	- Opened automatically 345kV SWYD PCB 7100/7272
20:34:31	EDG B auto-start signal on
	MCR operator found EDG 'B' fail to start
20:36	Failed to manual EDG 'B' start
20:40	Decided restore power using SAT 'A' without declaration of emergency action level "Alert (White)"
20:46:13	Closed breaker on SAT 'A' (SBO for 11min. 43sec)
20:52:41	Started Component Cooling Water pump
20:53:47	Started RHR pump 'B'
	- Hot leg temperature increased from 37 °C up to 58.3°C and after that gradually decreased to its normal value
20:53~21:30	Plant manager instructed staff not to log and not to report the event
<u>Feb. 10 2012</u>	
13:00	Finished SAT 'B' maintenance
18:47	Started fuel transfer from reactor vessel to spent fuel pool
<u>Feb. 11 2012</u>	
09:00	Originally planned end of SAT 'B' overhaul
	Originally planned start of UAT maintenance package which includes the generator relay test
22:00	Completed fuel transfer
<u>Feb. 12 2012</u>	
18:45	Finished EDG 'A' functional test (in standby mode)
<u>Feb. 13 2012</u>	
10:00	Started maintenance for EDG 'B'
<u>Feb. 22 2012</u>	
13:00	Finished EDG 'B' functional test (in standby mode)
<u>Feb. 26</u>	
	EDG-B failed to start in bus transfer test on the undervoltage demand signal

	The event was logged in the shift logbook and the CAP programme, but CAP entry was closed as category 3 event: not safety significant
<u>March 3 2012</u>	
	Reached reactor critical
<u>March 6 2012</u>	
	Reached 100% power after overhaul
<u>March 10 2012</u>	
	Reported SBO to newly appointed site manager
<u>March 11 2012</u>	
	Reported SBO to CEO of KHNP
<u>March 12 2012</u>	
22:00	Reported SBO to NSSC NSSC ordered shutdown of Kori-1 started power decreasing for reactor shutdown Kori 1 event unveiled to the public via press release
<u>March 13 2012</u>	
22:35	Started special inspection by Regulatory Body (NSSC/KINS) Shutdown reactor
<u>March 15</u>	
	EDG-B failed to start during special test requested by NSSC Failure to start was determined to be due to malfunctioning of start-up air supply solenoid valves.
<u>March 16</u>	
	Release of Interim Investigation Report by NSSC Report included EDG performance test results which had been performed on 15 March, story behind notification delay and plant non-compliance in reporting, and plant safety assessment.
<u>March 20</u>	
	Close out of first Investigation by NSSC An additional investigation and technical review is in progress
<u>April 16</u>	
	INES Event Rating 2 (Incident) issued by MOST
<u>April 23</u>	
	Preliminary International Incident Report (IRS) number 8229 on the event received by IAEA

The repeated cases of failure of EDG B are listed in the following table:

Cases of failure of EDG B

Title of report	Test	Date of Event	CAP Register	Test - Why	Direct cause
Safety bus B train power loss during K1 OH	Generator Protective Relay Test	'12. 2. 9	'12. 5. 23	Every OH test by Technical Spec.(Electronic dep.)	malfunction of air supply system solenoid valve
K1 EDG B Startup solenoid inspection	onsite power switch test	'12.02.26	'12.02.26	Every OH test by Technical Spec. (Electronic dep.)	malfunction of air supply system solenoid valve
K1 EDG B Startup failure cause analysis	onsite power switch test	'12. 3. 15	'12. 3. 15	Retest on current condition after SBO event by KINS request	malfunction of air supply system solenoid valve
K1 EDG automatic shutdown inspection	EDG B 24th function test	'12. 5. 17	'12. 5. 17	25th function test after EDG B solenoid valve dualization by KNIS/NSSC request	error due to STOP timer relay surge at startup circuit

2.2 Analysis performed by Kori 1 NPP, KHNP and NSSC

Nuclear Safety and Security Council (NSSC) has completed its Interim Investigation Report (16 March, 2012) and continues to perform additional investigation and technical review.

The Kori-1 plant has completed in-depth operating experience report “Loss of Offsite Power and Emergency Diesel Engine Failure” and sent it to KINS on 09 April 2012.

Preliminary International Incident Report (IRS) number 8229 on the event was received by IAEA on 26 April.

The plant has prepared the SBO event analysis report and KHNP Central Research Institute translated it into English language and sent to WANO Tokyo Centre. The report was posted on 18 May 2012 as WANO Event Analysis Report EAR TYO 12-002: Loss of Offsite Power and Emergency Diesel Engine Failure (09 February 2012, Kori Unit 1, KHNP).

KHNP has completed Interim Investigation Report “Loss of Offsite Power and Emergency Diesel Engine Failure” on 24 May 2012.

The Kori-1 plant is in a process of producing root cause analysis report “Loss of Offsite Power and Emergency Diesel Engine Failure (09 February 2012, Kori Unit 1, KHNP)” using event and causal factor chart and barrier analysis methods with completion target date 17 June 2012.

2.3 Event analysis by the IAEA EM team

The IAEA expert mission analyzed the event through dividing it into three parts:

- Station Black Out (SBO);
- Not reporting Station Black Out including not declaring Emergency Action Level “Alert”;
- Violation of Technical Specifications.

The analysis was performed by using a simplified barrier analysis described in section 3.4 of the draft ROOT CAUSE ANALYSIS REFERENCE MANUAL being developed at IAEA for publication. The analysis was limited to determining the direct and contributing causes of the three events and proposing corrective actions for those contributing causes which have not been yet addressed by the NSSC Interim Investigation Report or by the on-going event analysis by Kori 1 NPP.

The IAEA EM team did not make an attempt to identify root causes for these events, since any root cause analysis method would require more time and resources than the team had available. The root causes (why it was possible) - will be determined by the root cause analysis being performed by Kori NPP utilizing event and causal factor chart and barrier analysis.

During its analysis the team used the following definitions:

Direct cause: The immediate cause of an event or adverse condition. The failure, action, omission or condition that directly leads to an initiating event.

Contributing cause(s): Contributing Causes are important in the anatomy of an event in that contributing causes exacerbate the issue or the event. A test of whether a cause is a contributing cause instead of a Root Cause is whether permanent correction of the contributing cause will prevent recurrence of the event. If “why” is asked until it becomes unreasonable or unrealistic to fix the issue, and the event can still occur once this cause is corrected, then only a Contributing Cause has been identified. It is still important to initiate Corrective Actions to prevent the contributing causes as these causes could result of contribute to another event or issue of lesser significance if not corrected.

Station Black Out (SBO)

Direct cause (why it happened): Mis-operation of the protective relays of the main generator

Contributing causes/broken barriers:

- Scarcity of contractors qualified for test of generator protection system – this was the reason for rescheduling the test, because of time pressure for the available contractors to move to next work site
- Rescheduling the generator protection system test bypassing established process (to be approved by Outage Control Centre), this resulted in lack of additional risk analysis for the unusual lineup for the test – See Maintenance section of the report
- Maintenance of SAT B was started although SAT A was not returned to operation, this resulted elevated shutdown risk – See Maintenance section of the report
- Design: single solenoid valve for startup air for DG. Corrective action: As a part of a root cause analysis of the SBO event the plant should extend conditions of the EDG-B solenoid valve failure and perform analyses of other plant’s equipment and systems important to safety to identify and manage critical parts and components and its vulnerabilities (similar to EDG-B solenoid valve), to avoid repeat events.
- Maintenance: no complete preventive maintenance, ‘lost’ rubber cap was replaced by a plastic cover not providing proper protection – See Maintenance section of the report
- Human error of communication: supervisor instructed “do not proceed to next step”, worker activated next channel during generator protection test – See Safety Culture section of the report
- Human factor: overconfidence of worker due to long experience with this test – See Safety Culture section of the report
- Procedure: preconditions, potential risk and consequence of error not described; no requirement to sign off completed steps – See Maintenance section of the report
- Pre-job brief was performed one day before the test, although “it should be used as means of avoiding personal errors, difficulties in communication and misunderstandings” (NS-G-2.14; 4.27)

Not reporting Station Black Out including not declaring Emergency Action Level “Alert”

Direct cause (why it happened): Kori 1 plant manager and other staff decided not to report SBO – See Safety Culture section of the report for all contributing causes

- Contributing causes/broken barriers:
- Reputation risk: That time plant manager stated he decided to hide this event due to heavy feelings of a burden to preempt public critics and a fear of worsening the plant's credibility
- Decrease of public trust in Kori 1 NPP associated with Fukushima accident, reactor trip at Kori 1 in April 2011 and two cases of corruption related to supply of spare parts for Kori 3 and 4
- Undue pressure from KHNP to operate without events
- The prevailing high respect for authority of supervisor prevented other staff involved to disagree with plant manager, although several elements of safety policy and administrative procedures were violated
- Kori 1 safety culture survey from May 2012 indicates that:
 - Relatively few (only 23.2%) of plant staff provided positive response to whether “safety culture is regarded as the most overriding priority in performing any activity”
 - Relatively few (only 19.5%) of plant staff provided positive response to whether “business environment that put an importance on the safety is created”

Violation of Technical Specifications

The plant Technical Specifications were violated by a) not immediately starting to take action to restore EDG to operable condition by the afternoon shift on 9 February; b) starting of fuel movement with no operable EDGs by the afternoon shift 10 February (in fact the same shift was on duty on the two occasions).

Direct cause (why it happened): EDG B was not declared inoperable as a part of ignoring the previous SBO

Contributing causes/broken barriers:

- Decision of Kori 1 plant manager not to report SBO – See Safety Culture section of the report
- Other involved staff did not oppose/disagree with PM’s decision, although several elements of safety policy and administrative procedures required that action – See Safety Culture section of the report
- Incoming night shift failed to identify status change (increase of primary coolant temperature on chart recorder, alarm of “RHR flow low” and “RHR trip” on the alarm printer); although relevant checks are required in general, but detailed checklist does not exist – See Operations section of the report

- Kori 1 internal oversight failed to identify SBO event – See Management, Organisation and Administration section of the report
- NSSC/KINS inspectors failed to identify SBO event – See Management, Organisation and Administration section of the report

Safety Significance of the SBO event

There was no radiation exposure to the workers or radioactive materials released to the environment. During loss of shutdown cooling for 19 minutes, the reactor coolant maximum temperature in the hot leg increased from 37 C to 58.3 C (approximately 21.3 C increase), the temperature of spent fuel pool increased slightly from 21 C to 21.5 C. No fuel damage was identified based on RCS I-131 activity analysis and thermal hydraulic audit calculation.

3. MANAGEMENT, ORGANIZATION AND ADMINISTRATION

3.1. Kori site organization

Kori unit 1 is organized together with unit 2 (see subsection 1.3.4 of the report). The organization includes three offices; operations, maintenance & engineering, and a temporary office set up in order to facilitate the large volume of modernizations that is currently being introduced into Kori-1.

The operations office has six control room shift teams for each unit, a radiation protection team, a chemical engineering team, and an operational management team that supports the operations office with coordinating activities, tracking of training qualifications and performance and tracking of surveillance tests.

The maintenance & engineering office is organized in three teams for maintenance of mechanical, electrical and I&C equipment, respectively. In addition there is a separate team for analyses of plant status and a team for outage planning and special programs.

In order to support the organization with analyses of different cross-functional areas, a separate safety and engineering support team is set up. This team monitors and analyses the plant performance in several aspects, including nuclear safety, industrial safety, human performance, safety culture, core management, and fire protection. The team is also responsible for the probabilistic safety analysis and the periodic safety analysis. In addition there is also a separate group for maintenance of the building structures.

At the Kori site there is a quality assurance function common to all units. It is responsible for the control of procedures and quality documents related to contractors and materials. The QA-function also oversees equipment installations and surveillance testing in the plants.

Recently, on May 9 2012, a new team for independent inspections was set up on Kori site level. The team consists of personnel on shift duty who performs inspections or surveillance tests and other plant activities around the clock. The findings from this group are reported on a daily basis to the site vice president and to KHNP headquarters. As the team was set up only recently, its duties are still under development and an evaluation of its effectiveness is scheduled for the end of 2012.

3.2. KHNP corporate organization

Although the Kori vice president is reporting directly to the president & CEO of KHNP, there are many interfaces between the Kori site organization and the KHNP corporate organization.

The four divisions of planning & administration, power generation, safety & technology, the construction all interact intensely with the Kori organization.

The planning & administration division is responsible for budget issues, general planning and procurement.

The power generation department within the power generation division is responsible for oversight, performance analysis and development of improvement plans in a wide range of areas related to nuclear safety and plant capability, including a chemical engineering team. The department is also responsible for the production planning for the KHNP generation fleet. Within the division there is a regulatory compliance team that interacts with the NSSC. The regulatory compliance team coordinates the KHNP Nuclear Review Board (KNRB). This board, with members from outside of the KHNP, is instituted to review and check safety related issues independently from plant operation.

Within the power generation division, there is also a plant engineering & management department. It is mainly dealing with component reliability and maintenance issues, including improvement of maintenance methods, assessment of seismic resistance and life-time management.

Within the safety & technology division the safety and environment department establishes the safety policy, assesses safety culture and develops safety culture campaigns, manages the reliability assessments and handles issues related to radiation safety and waste management. In addition, this department is responsible for the post-Fukushima response activities. The emergency management office deals with emergency responses in case of fire, natural disasters and nuclear accidents. It is also responsible for industrial safety issue. The KHNP central research institute conduct research on mechanical, electrical and I&C matters and provide technical support

The construction division is responsible for budgeting, planning, licensing and design of plant modifications.

3.3. Management & Organization of the Kori site

Safety policies are clearly defined and advertised to the staff through direct information to the staff, through the intranet, banners and posters, etc. The safety policy is defined on the corporate level and advertising is in general driven from the organization where it was developed. There is room for local initiatives and such examples can be demonstrated.

There is at present a system for reporting of safety concerns at Kori through the corrective actions process. However, many employees find it difficult to report concerns regarding the behavior and actions of superiors and peers. A box where anonymous notes can be mailed to

the management is available but is never used. The reporting system should be developed in a way that encourages also the reporting of information that is deemed sensitive or compromising to individuals in authority within the organization.

For the surveillance of safety and operational parameters, the Kori site relies on WANO performance indicators and a set of indicators developed by KINS. The latter is used on a Korean national basis.

The KINS safety index is composed with 11 criteria (WANO SP1 SP3 SP5, Unplanned shutdown, collective radiation exposure for KHNP and contractors, Fuel integrity, Primary leaks, Containment leaks...). The global result (Green, Blue...) is on Internet. A global self-assessment process exists, but each department chooses each year what areas it will assess. Nuclear safety is not systematically self-assessed. For the main parameters, the trends are followed by the Department concerned (mechanical, electrical, chemistry, operation...) Kori 1 uses an Equipment Reliability Index (8 domains and 19 criteria) since July 2012, based on the INPO AP913 method.

It is noted that, for the Korean nuclear fleet, at the end of 2011 only three KINS indicators (out of totally 231) were blue (the second best rating) and all the others green. At the end of the third quarter 2011 all the KINS indicators were green. This indicates that the KINS indicators as presently defined are not supporting the continuous improvement of the performance of the Korean nuclear power plants.

Performance indicators are also available in the form of a score card that reflects other areas of the stations results and objectives. The score card is a part of the incentives system for the staff. The score card is in many instances made up through an aggregation of data into indexes. There are also very few parameters in the score card that visualizes the effectiveness of administrative parameters.

The responsibility for oversight of plant activities is well defined. The responsibilities for this organisational unit is, however, not only to monitor and review the activities within the plant organisation, it is also to be a part of the development of corrective actions when needs are identified. This is resulting in an unclear situation where the oversight unit in practice also should perform oversight of the implementation and effectiveness of corrective actions decided within the same unit.

The safety related oversight activities are sometimes not performed according to detailed procedures with respect to which information or activities that should and when they should be performed. This gives room for inconsistencies in the oversight standards and difficulties to improve routines when experience is gained.

Remarks resulting from the oversight process are sometimes not presented in a formal way to the line organisation. Thereby it is difficult to evaluate the effectiveness of the plant oversight process.

An internal safety committee (PNSC) is active and its duties are defined in an instruction. It is performing reviews of plant modifications and changes in the plant documentation and also reviews events and other safety issues.

There is a system in place where managers routinely observe the performance of work tasks in the plant. This is performed according to a schedule where the observation of duties are rotated among the managers.

A routine for the management of organizational changes is in place. The routine includes approval by the NSSC when nuclear safety is affected.

A staff health policy is in effect. Medical tests are performed once per year, including psychological tests for operations personnel.

There is a succession planning in place for operations but not for maintenance. For the replacement of personnel within the maintenance organization the station is relying on the strong resource body of the entire KHNP corporate organization.

Besides a temporary office for plant modifications, the staff sizing for Kori 1 and 2 is basically the same as for the other Korean unit pairs. However, it is likely that the operation of two reactors of different design and from different suppliers, would require more resources than for other unit pairs in Korea. This is due to the fact that there has to be separate sets of procedures, maintenance plans and spare parts for each unit. In addition, an increasing amount of refurbishments with age will add to the workload. Hence, it is advisable to perform a review of the resource adequacy for the special case of Kori 1 and 2.

Contractors are supervised by the operating organization. Contracting companies are responsible for all parts of training for their staff, including radiation protection and nuclear safety. The operating organization checks that relevant courses have been taken. The quality of the training is reviewed independently by KHNP, however not when subsidiaries of KHNP are concerned.

3.4. Relations between the Kori site and the KHNP corporate organization

The oversight structure and responsibilities at the corporate level is with the power generation department of KHNP and has similarities with that of the site organization, with the same risks for unclear responsibilities and loss of independence. The contacts between the corporate oversight organization and the Kori site are intense. The oversight bodies at the corporate and site level can in many respects be seen as two branches of the same

organization. Major initiatives for changes of processes and routines are normally developed at the corporate level. With respect to oversight, this also obscures the interface between the corporate and site organizations.

At the corporate level there is a review board (KNRB) with members also from outside of the KHNP. Like the local safety committee (PNSC), it is to review plant modifications and changes in documentations, events and nuclear safety issues but with a selection of only the most significant one's. The role and responsibilities of the KNRB is defined in an instruction. The board reviews these areas for the whole KHNP nuclear fleet. Although the review board should review events and general nuclear safety issues, there is no evidence that this type of issues are dealt with in the review board.

Although reporting to the president and C.E.O. of KHNP, the site organization is strongly influenced by at least three different corporate divisions. Also, interactions within the corporate organization are many and frequently not possible to define in terms that can be reflected in an organizational chart. Although responsibilities are clearly defined in the technical specifications, FSAR, and corporate regulations, overlapping or very similar responsibilities can sometimes be found in different parts of the corporate organization, for example in the closely related areas of human performance and safety culture, and with regard to corrective action plans resulting from event. This may not be wrong, but it requires a high degree of coordination at both the corporate level and the site level in order to meet the overall objectives of plant safety and performance. Furthermore, the order of priority for initiatives as well as the consequences on the work load on the site organization can be difficult to assess in the decision making processes.

3.5. Relations with the regulator

The regulatory authority (NSSC) and its technical support organization (KINS) have resident inspectors at the Kori site. The resident inspectors have free access to the site. Routines for reporting of events and the necessary routines for information exchange between the Kori site staff and the resident inspectors are defined and in place. Regular contacts between the NSSC headquarters and the KHNP headquarters are established and also between the local head of NSSC and the Kori vice president.

The resident inspectors are well qualified and are certified. They have a good educational background and good nuclear and inspection experience. They are in addition subject to supplementary basic training for their specific work tasks and they are also regularly retrained.

The inspectors work according to guidelines that are not specified in detail. On a daily basis they perform routine inspections on the site and supervise surveillance tests. This includes verification of operational parameters and that the units are kept within the technical specifications. In addition to the daily inspection activities the inspection program includes audits of various specialized areas according to a schedule made up on a yearly basis. Best practices are the detailed procedures for the work tasks performed by the resident inspectors including what to observe and the frequency for these observations.

Recommendations from the resident inspectors, based on the daily inspections are recorded in inspection reports that are released to the station. Responses on the activities performed by the station based on these recommendations are tracked.

It is noted that, when deemed to be of minor significance, remarks by the resident inspectors are sometimes given orally to the individuals concerned in the Kori staff instead of presenting them in a formal report.

KINS are reporting their findings to NSSC on a daily, weekly, and yearly basis. Abnormal conditions such as violations of the technical specifications are reported as soon as they are identified. In case of an abnormal condition, initial investigations are performed by the resident inspectors. When deemed appropriate, teams with special competence are brought in for in-depth evaluations.

The resident inspectors perform few unannounced inspections. After the station black-out event, the number of resident inspectors from KINS has increased from three to eight. This allows for inspections also during evenings. During nights there is a resident inspector at the site but he is not actively performing inspections. During weekends and holidays personnel from NSSC visits the main control rooms on a daily basis. It is noted that international practice is that resident inspectors perform unannounced inspections of the units during off-hours.

Because the SBO occurred in the evening, there were no resident inspectors on site at Kori. Hence, there were no obvious signs of a black-out situation that could be detected by the inspectors. During the daily inspections the day after, the focus of the inspector was on Kori unit 2 that was in full operation. When visiting the main control room of Kori unit 1 in the morning after the SBO, the situation was normal and with no abnormal alarms. As entries into the logbooks were not performed and checks of the alarm lists were not a mandatory daily routine, the SBO was not discovered by the inspector.

DETAILED MANAGEMENT, ORGANIZATION AND ADMINISTRATION FINDINGS

3.1. Issue: The organization does not strongly enough support the reporting of improper behaviors of individuals, nor improper decisions made by management, on issues related to nuclear safety.

At the site, there exists a system for reporting of problems and events, also for events of a very low significance. The system is well advertised and the use of the system is strongly encouraged by management. However, reporting of situations related to improper decisions, actions or behaviors by peers and managers is from a human perspective, difficult and needs additional support.

- Reporting of actions by managers and peers is described as “difficult” during interviews.
- During the SBO event, staff who were aware of the improper decision made by management was not reported to higher levels in the organization
- The mail box available for anonymous reporting is not used

Improper behavior and improper operational decision making may not be brought to attention and hence corrective actions cannot be instituted.

Recommendation: The plant should ensure that the reporting system more strongly supports the reporting of improper issues, actions and behaviors by individuals.

IAEA Basis:

GS-G-3.1

2.18. Managers and supervisors should encourage and welcome the reporting by other individuals of potential safety concerns, incidents and near-misses, and accident precursors, and should respond to valid concerns promptly and in a positive manner. Where appropriate, contractors should give the same high priority to safety, especially when they are working at a facility.

2.36 Open reporting of deviations and errors is encouraged.

6.15. Senior management should reinforce a questioning attitude in individuals and should encourage the discovery and reporting of all areas needing improvement. Managers should avoid punishing or intimidating individuals for unintentional errors and should not react defensively to suggestions for improvement.

3.2. Issue: Management goals on operational safety are sometimes not challenging with regard to nuclear safety. When aggregated indicators are used, good performance in one area

may obscure deficiencies in others. On the site level there are few indicators related to work processes.

Goals and indicators are often aggregated from various inputs on a lower level. In doing so, important information regarding deficiencies in underlying areas may be lost. The system for operational indicators, collected and published over the internet by KINS, is almost always showing “green” signals and hence not support efforts for continuous improvement.

Although goals and indicators for operational safety exist and are used, the following has been found during the review:

- On a nationwide basis the KINS performance indicators showed only three “blue”, second best rating, indicators for the Korean nuclear fleet (out of a total of 231) at the end of 2011. At the end of the third quarter 2011 all indicators were “green”.
- In the site indicator system, on which staff incentives are based, several indicators are aggregated. Of special significance is that safety performance is an aggregated index.
- The site indicator system is again aggregated into a total score with a maximum of 100 points. Only 22 points is related to nuclear safety, radiation dose, and industrial safety.
- No indicators on the effectiveness of processes related to the administration of routines supporting operational safety (back log, lead times) are included among the site indicators.

Without a relevant set of goals, targets and indicators for nuclear safety performance, management oversight of nuclear safety may be obscured.

Suggestion: The plant should consider an internal assessment system with performance indicators that gives more challenges to the status of safety related issues other than those directly reflecting the reliability of systems or components. On the corporate level a set of more challenging indicators on nuclear safety should be considered. Furthermore, the status of administrative support routines should be visualized in the indicator system.

IAEA Basis:

SSR-2/2 Requirement 9

4.34. Self-assessment by the operating organization shall be an integral part of the monitoring and review system. The operating organization shall perform systematic self-assessments to identify achievements and to address any degradation in safety performance. Where practicable, suitable objective performance indicators shall be developed and used to enable

senior managers to detect and to react to shortcomings and deterioration in the management of safety.

NS-G-2.4

5.20. To monitor safety performance in an effective and objective way, wherever possible and meaningful, the relevant measurable safety performance indicators should be used. These indicators should enable senior corporate managers to discern and react to shortcomings and early deterioration in the performance of safety management within the train of other business performance indicators.

3.3. Issue: The group for oversight of the nuclear activities at Kori unit 1 and 2 does not have an independent status relative to the organization and more stringent criteria for observations and reporting should be developed.

Kori unit 1 and 2 have established an organization for oversight. It is however not independent to the rest of the organization. This is of special importance since the major initiatives for change are developed in the oversight groups at the site and at the corporate level. Procedures for what, when and how reviews and inspections should be performed are not prescribed.

- The group for oversight (“investigation part”) is under the team leader for Safety & Engineering Support who reports to the Kori unit 1 and 2 manager, who may be directly affected by the findings made.
- The group for oversight is under the direct influence of the corresponding group at the corporate level.
- Together with the oversight body at the corporate level, corrective actions are developed. As a consequence the effectiveness of corrective actions may be evaluated by the same group that developed them.

Without an independent oversight at the site a proper evaluation of nuclear safety and the consequences of initiatives for change may not be achieved.

Recommendation: A group with independent status should be introduced for oversight of nuclear activities, including a set of detailed procedures for what, when and how reviews and inspections that an independent oversight body should review.

IAEA Basis:

SSR-2/2 Requirement 9

4.35. Monitoring of safety performance shall include the monitoring of personnel performance, attitudes to safety, response to infringements of safety, and violations of operational limits and conditions, operating procedures, regulations and licence conditions. The monitoring of plant conditions, activities and attitudes of personnel shall be supported by systematic walkdowns of the plant by the plant managers.

GS-R-3

6.3 Independent assessments shall be conducted regularly on behalf of senior management:

- To evaluate the effectiveness of processes in meeting and fulfilling goals, strategies, plans and objectives;
- To determine the adequacy of work performance and leadership;
- To evaluate the organization's safety culture;
- To monitor product quality;
- To identify opportunities for improvement.

6.4. An organizational unit shall be established with the responsibility for conducting independent assessments. This unit shall have sufficient authority to discharge its responsibilities.

3.4. Issue: The organizational unit for oversight of the nuclear activities at KHNP does not have an independent status relative to the corporate organization and is responsible in parallel for the development of major corrective actions within the nuclear fleet. The KHNP review board does not fulfill all tasks assigned to them.

KHNP has an established organization for oversight. It is however, not independent to the rest of the operating organization. The group is performing oversight and at the same time is responsible for the development of significant corrective actions within the entire KHNP nuclear fleet.

In the course of the review, no examples have been found where the corporate nuclear review board, KNRB, have reviewed events and general nuclear safety issues although this is one of paramount responsibilities of the board.

- The group for oversight on the corporate level, within the Power Generation Department, is at the same time developing major corrective actions within the KHNP nuclear fleet.

- Although not shown in the organizational chart, the group for oversight on the corporate level is in reality in the direct line of order when major corrective actions and initiatives are developed and initiated.
- When reviewing the minutes from the past seven meetings with KHNB, picked at random, none of these meetings have addressed plant events or general nuclear safety issues.

Without an independent oversight within the corporate organization, a proper evaluation of nuclear safety at the sites and the broader consequences of corporative initiatives for change may not be achieved.

Recommendation: The organizational unit for oversight of the nuclear activities with an independent status within the KHNP should be established.

IAEA Basis:

SSR-2/2 Requirement 9

4.35. Monitoring of safety performance shall include the monitoring of personnel performance, attitudes to safety, response to infringements of safety, and violations of operational limits and conditions, operating procedures, regulations and licence conditions. The monitoring of plant conditions, activities and attitudes of personnel shall be supported by systematic walkdowns of the plant by the plant managers.

GS-R-3

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- To monitor product quality;
- To identify opportunities for improvement.

6.4. An organizational unit shall be established with the responsibility for conducting independent assessments. This unit shall have sufficient authority to discharge its responsibilities.

4. SAFETY CULTURE

4.1. The concept of Safety Culture

The term Safety Culture has its roots in the end of 1980s where a growing understanding was realized that safety management systems and associated good procedures were not adequate to ensure safety if merely practiced mechanically, without the attitudes, values and behaviors aligning with the intent of actively managing, supporting and improving safety. As the study of this intangible concept continued, it developed into tangible identifiable characteristics and attributes which included leadership and behaviors inside nuclear facilities. Since that time a good understanding of assessment and development principles have been captured, tried and tested in different types of Nuclear facilities worldwide. This concept is not confined to nuclear facilities as the majority of High Hazard industries have also developed an understanding of their safety culture characteristics, many of which are in common with nuclear safety culture.

IAEA has a number of publications where the understanding of the concept and the practices of assessment and development have been recorded. These were used in the review of Kori 1 Safety Culture.

In considering the safety culture, it is known that the organization will already have a safety culture in some form that will have been influenced by the organizational culture, the organization's history and experience, and other major cultural forces (e.g. the national culture). The challenge is to develop the existing safety culture for the organization's future success. Changing or developing the safety culture should not be an end in itself it should be a means of moving the safety culture so that it contributes to achieving the goals of the organization whilst ensuring safe operation and programs.

4.2. Some aspects of Korean Culture

In discussion, the Korean national culture attributes of respect for elders and superiors came to have significance. The strength of this cultural attribute is that compliance with line manager's requirement and expectations is good but puts a reliance and greater responsibility onto the leader to show an exceptionally good code of conduct, standards and leading the team to excellence. This attribute also has an implied effect on 'questioning attitude' which needs to be accommodated to ensure that this safety culture characteristic is working inside KHNP. Where a line manager chooses to work outside policy and procedures there may not be an acceptable cultural route for a worker to raise a question.

In discussion, a cultural aspect of 'working hard and fitting as much activity into the time as possible' emerged. The strength of this characteristic is that managers can use the Korean work ethic to complete tasks efficiently and quickly, however the difficulty with the characteristic is that detail and systematic completion may be compromised. 'Check lists' and

quality/procedural ‘hold points’ that are used extensively at the site could help counter the problem.

4.3. Aspects of KHNP Culture

KHNP culture is a technical culture with many engineers and scientists who are used to looking at technology and associated science. Most Nuclear Generation facilities in the world are of this type. The strength is that knowledge is applied and safety is assured through competent application but it also leads to a complete focus on technology rather than accepting that a plant is also a community with associated social aspects which effect performance. Safety Culture depends on the harmony between technology and people. The team found that KHNP have imported the ideas and good practices from the worldwide nuclear community and are actively trying to balance the technology and people through communication and training. But KHNP need to ensure that the methods and techniques are modified to fit the Korean culture to achieve the same outcomes.

4.4. Safety Culture Development

Safety culture excellence was identified through INSAG 4 as being characterized by good:

1. Questioning Attitude
2. Rigorous and Prudent Approach
3. Communication

These were further developed into Characteristics in Management System for Nuclear Installations GS-G-3.5 as :

1. Safety is a recognized value
2. Accountability for safety is clear
3. Safety is learning driven
4. Safety is integrated into all activities
5. Leadership for safety is clear

For each of these, Kori unit 1 was reviewed to understand the strength of these characteristics and any compromised areas which could have led to the SBO event.

Kori unit 1 has a strong foundation for safety culture in communication of training, awareness raising communications, leadership training, and use of human performance tools. They have a continued improvement program which directly seeks to improve safety culture for example ‘Safety Guardians’ selected from senior management are being appointed to promote practical on-site nuclear safety culture activities and they are trained by KHNP HQ by industry experts and academic staff on fundamental practices and principles for both peers and subordinates. Safety Culture training and Leadership training are also mandatory in KHNP.

However, in reviewing the SBO event and other events a number of indicators emerged which showed a safety culture which has difficulty when faced with an unexpected or challenging situation. This challenged the “Rigorous prudent approach” in that the process for the rescheduling the test and the procedures used during the test were not in accordance with this character. “Communication” and “Questioning attitude” were also challenged in the follow-up action and leadership reporting errors. The wider cultural aspects were also considered when considering the leaders actions, and the background influences that led to the degradation of safety culture.

4.5. Contributing causes/broken barriers to the SBO event

Wider Cultural influences leading to behavior:

- High respect for authority of supervisor prevented other staff involved to disagree with plant manager, although several elements of safety policy and administrative procedures would require that the plant blackout was a situation that required onward reporting and initiation at the time of a readiness emergency arrangement response.
- Decrease of public trust in Kori 1 NPP associated with Fukushima accident, reactor trip at Kori 1 in April 2011 and two cases of corruption related to supply of spare parts for Kori 3 and 4

Internal Kori cultural influences

- Reputation risk: At that time the plant manager stated he decided to hide this event due to heavy feelings of burden to preempt public critics and a fear of worsening the plant's public credibility
- Undue pressure from KHNP to operate without events

In a subsequent Safety Culture survey at Kori 1, the results supported the view that the Kori 1 workforce and managers felt that business priorities are put ahead of the safety priorities.

4.6. Conclusions

1. **‘Safety is a recognized value’** : Kori unit 1 has a strong foundation for safety culture in communication and training programs for safety culture for both managers and the workforce during day to day work, so that the common understanding of key aspects of safety culture are transparent to all who work on the site.
2. **‘Safety is a recognized value’** : The findings of the Safety Culture survey particularly in the area of business priorities need to be tackled by the leadership and clear, reinforced messages sent out to the workforce. These will need to be demonstrated by example and continued vigilance.
3. **‘Safety is a recognized value’, ‘Leadership for Safety is clear’ and ‘Questioning Attitude’**: The safety culture at Kori unit 1 was unable to counter the errors

committed in the SBO event nor the subsequent leadership failures in communication and reporting. The Kori unit 1 Safety culture needs to support Leadership in decision making and develop stronger defenses when facing unexpected and difficult situations. This is due in some part to the influence of the national culture with the respect of seniority in the hierarchy, which through social pressure would not encourage challenge to a decision made by a higher rank line manager, and prevent alternative communication. Degradation of Safety Culture can be created by the workforce observing deviations from expected behaviors, and lack of adherence to site policy and instructions. Where such deviations are observed, questioning attitude and communication of the issues will decrease, and copy attitudes and behaviors will follow, particularly when no consequences are experienced. In terms of Safety Culture this is seen as ‘normalisation’ of abnormal conditions, and workforce and leaders become accepting of the abnormal condition. With the observed leadership behaviors having such a large impact, there is more responsibility on leaders to show their attitudes and values towards Safety Culture in both day to day operations and when dealing with unexpected and difficult situations.

4. **‘Safety is Learning Driven’:** Safety Culture assessment has been carried out by KHNP on Kori unit 1 post SBO. The methods they used has been developed using good practice and discussion with experts so that it can be delivered to suit the organization and culture. The findings of this survey will give rise to corrective actions to assist in the further development of Kori unit 1 safety culture.
5. **‘Safety is Learning Driven’:** Operational experience is used throughout the facility to develop the stations learning culture. The OE service provides analysis, and consideration of Human factor and organizational/behaviors are identified in the reports. However, the root cause analysis does not develop the investigation into the root of the organizational and behavioral ‘ineffective barrier’ which may lie in safety cultural characteristics and attributes. This is required to understand the origin of the event’s root causes beyond the straight forward equipment and management system failure, and address the cultural roots of events. This would not be necessary in all events but those which have specific consequences (both safety and business) or where unacceptable behaviors and latent failures had been identified.
6. **‘Safety is learning Driven’ and ‘Questioning Attitude’:** An anonymous employee concerns reporting scheme has been suggested by the results of the Safety Culture survey. The team would strongly encourage the organization to follow through with this scheme with the Leadership showing strong support in both maintaining anonymity and taking visible action to identify appropriate assessment and action. Such schemes are in place in other nuclear facilities and support questioning attitude in unexpected and challenging situations. Another route for ‘questioning attitude’ is through the worker representative discussions between union labor and management.
7. **‘Safety is integrated into all activities ‘and ‘Communication’:** Kori unit 1 has a split workforce between KHNP workers and contractors (largest being a subsidiary of

KHNP called KPS). They are separate in both management and visibly different in uniform. The team has also found separate of safety culture development activities through separate training with minimum control by KHNP, and procedures that were owned by the contractors with minimum input by KHNP (note: following SBO electrical procedures are now controlled by KHNP). These separate systems may lead to the development of different safety cultures and unless alignment activities take place, this may lead to different standards and expectations leading to communication and work quality issues.

8. **‘Safety is integrated into all activities’ and ‘Rigorous prudent approach’:** The team found that there was indication of a safety culture that did not pay attention to details. This can have a cultural origin in that where the common cultural trait is not for detail. This may lead to ad hoc checks and sequence of task may be inadequate to maintain situation awareness and quality of equipment.

4.7. Improvement proposals:

All methods and techniques imported from good practices used in other countries must be adapted for use within the Korean culture to achieve the required outcome.

1. The safety culture training and Leadership programs need to emphasize and coach that the safety culture characteristics need to be maintained during unexpected conditions or issues. This includes; unexpected equipment conditions, planning conflicts, observed unacceptable behaviors by leaders/workforce /contractors, unexpected risks or hazards.
2. The safety culture assessment tool should be applied across KHNP and further developed to give an understanding of any differences of attitude between workforce and leaders.
3. Learning
 - a. By developing the investigations and ‘root cause analysis’ further, organizational and behavioral lessons may be identified to further enhance the learning and in particular for the leadership, such that corrective actions can be based on organizational safety culture roots as well as local failures. Analysis of areas of human factors may also be enhanced such that design of equipment and management systems may be considered and roots of error corrected or made more visible.
 - b. Continued use of ‘warning flag’ communications using appropriate OE examples should continue
4. The anonymous reporting scheme for employee concerns should be put in place with appropriate leadership support.
5. KHNP should review the safety culture development of long term contractors, the control of standards and expectations for short term contractors and align them with KHNP safety culture development.

6. KHNP should consider the methods appropriate for their safety culture to improve the management of required checks, monitoring and completion of tasks.

5. OPERATIONS

5.1. The management and organizational structure of the Operation Department

The organization of the Operation Department is clear and in compliance with the main international standards.

The structure of the operating organization and the functions, roles and responsibilities are clearly established and well documented.

The Shift Supervisor on duty has the primary responsibility for nuclear safety. He has the responsibility for the activation of the Radiation Emergency Plan. The shift supervisors report directly to the Deputy General Director in charge of Operation for unit 1 and unit 2.

There are 6 operating shifts, each with 9 qualified staff, with 5 of them in the Main Control Room (one Shift supervisor, one Shift Technical Advisor, one Reactor Operator, one Turbine Operator, and one Electrical Power Operator) and 4 in the field. In normal operation, 2 shifts are off duty, 1 in training and 3 on duty. During outage, shift in training helps the Outage Control Center. In case of unavailability of a member on the shift on duty, a qualified person on duty is called to complete the shift team.

The Shift Technical Advisor (STA), has the role for reporting plant events, failures, confirming that the operators understood the plant modifications, assessing the findings and analysis of normal and emergency situations of the plant, evaluating of effectiveness of the CAP (corrective action programme), follow up of significant events, supporting team in the understanding of technical specifications, oversight on operations in MCR and in the field. The STA could challenge the Nuclear Safety issues. In case of disagreement within the shift team, between the Shift Manager and the STA, the sequence is as follows, until an agreement or a final decision-making:

- Discussion within the shift team
- Support function within operation
- Operation Deputy General Director
- Plant Manager through the Plant Nuclear Safety Committee (PNSC),

A programme is implemented that controls the plant risk during power operation. STA uses the RIMS (Risk Informed Management System) to evaluate automatically the Core Damage Frequency (CDF). The result of this evaluation is entered in the Shift Manager's logbook and it is not systematically given and independent check; however the Safety Support Team could check the result through the RIMS system if necessary. A control is implemented if the color of the Risk changes (Green, Yellow, Orange, and Red). The Safety Support Team produces a

monthly Safety Analysis to document the risk exposure using the data acquired during the periodic visits to MCR.

The day staff is composed of three groups which are in support of teams on shift:

- One operation management senior manager for efficiency and outage, power transaction, operation record, and assistance for operators, with the assistance of 4 other staff members;
- One support senior manager for organization, training qualification, procedure and assistance with the assistance of 4 other staff members;
- One surveillance test senior manager with the assistance of 6 technicians in charge of the planning and following for periodical tests.

The operation management senior manager and the surveillance test support senior manager have a professional experience of 17 years with 9 years as SRO and 10 years on shift with 5 years as RO respectively.

The Daily meeting, that is chaired by the Plant Manager, reviews and confirms the tests and work activities for the day. The meeting that the team observed was efficient and effective. The Plant Manager challenged some of the topics. However, there was no great challenge by the Operation department on the information provided by the maintenance department. The team has made a suggestion in this area. The Safety Message offered the opportunity to recall the importance of the use of the Human Performance tools. The Plant Manager concluded by talking about the Nuclear Safety as the first priority, and the importance to complete the Maintenance work effectively. The test scheduled on the EDG for the next day, which could impact visitors from local community witnessing the test, was mentioned at the end. Such activities are commonly referred to as “Safety and Transparency”.

The Corrective Action Programme (CAP) daily screening meeting follows the Daily meeting and is also chaired by the Plant Manager. The meeting observed was efficient. Communication with pictorial display of the problem avoided long discussions. During the daily meeting observed, there was no topic dedicated to Human Performance Tools on nuclear safety. The Plant Manager ended by saying that the staff has to take care of housekeeping, talking about the bolts and others things found by the EM Team during the visit in the field.

The Kori requirement is to have one PNSC per month. Some PNSC meetings are also required during outage periods and to review and approve the analysis following nuclear safety-related events. The EM team reviewed the number of Plant Nuclear Safety Committee meetings conducted since 2009 and it was an indications of how that the Plant Manager uses it to challenge nuclear safety. The high number in 2011 is in connection with the Fukushima event.

Type	2009	2010	2011	2012
“Normal”	14	18	34	10
Outage	5	9	2	16
‘Extraordinary’	2	7	6	1
Total	21	34	42	27

The Plant Manager comes to both MCRs every morning (not systematically on Saturday and Sunday) and checks the main safety indicators and the Shift Manager logbook. The 3-way communication was used in MCR during the electrical test implemented on Thursday morning, between the electrical manager and the shift manager. The “third step” (“confirm”) was not used. The access to MCR is limited through a digital access code. The EM team observed that the MCR had adequate lighting, climate control and the absence of unnecessary noise. The desks were clean from helmets, piles of books or papers. The number of lit alarms was high in the unit 1 because of the cold shutdown, and only 2 white alarms were lit in the unit 2 MCR. The shift manager and the operators were cognizant of the alarms. The shift manager and the STA knew the priority in works and tests endorsed during the Daily morning meeting.

The monitoring of the data recorded by Operators and Field workers through the SMART system is done by the OPMS (Operation Parameters Management System). The analysis is done by the Operators. The other recorded parameters and the data from OPMS if necessary, are analyzed by the System Health Engineers. If necessary, once or twice per year, the analysis reports are presented to Operators. For example: May 2007 – increasing of the flow after the first seal of the primary pump during 4 days before the outage, February 2005 – proposal to review the operational procedure concerning the Residual Heat Removal System.

All the data from the plant computer, the paper recorders and the logbooks are recorded by the I&C department. The data from DREAMS (SAP software) are recorded by the Site Computer Team and at the Headquarter level. The procedures completed with recorded data are converted to plant records by the Operational Test Support Team.

The operation support teams produce 4 types of reports:

- Operating Experience Reports: from 5 to 10 per year for Kori 1
- Transient Reports (if alarm, or out of normal control): from 2 to 3 per year for Kori 1
- Weekly operational parameters report
- The monthly main analysis Report

The first two are signed by the Plant Manager, and distributed on- site, and off-site to the other NPPs with approval of the two Deputy General Director (Operation, Maintenance & Engineering). The last two are internal for Unit 1 and signed by the Operational Deputy General Director.

5.2. Operational limits and conditions

The Operational limits and conditions process is in compliance with the usual practices. The unavailability of nuclear safety-related equipment is managed through the Technical Specifications. The unavailability could be declared after information is given by a field worker, by an alarm or after the results of a periodical test. They are recorded in the DREAMS computerized system (SAP). The operators in the MCR are familiar with the use of DREAMS, the computerized system adopted by Kori.

5.3. Qualification and training

The need for recruitment is generated by the Operational Support Senior Management, but the operational department is not involved in the choice of the candidate. The recruitment process is done at the KHNP level and the selected candidate is assigned to the plant. The process takes about 5 to 6 months. To avoid temporary lack of competencies in a shift team, a qualified person from the team in training could be used, and 2 or 3 qualified persons are generally available from the 6 teams.

The Plant Manager decides the internal recruitment (change within operation department) based on a document on qualification is prepared by the Training Department, and on a document on performance prepared within Operation department. The Plant Manager decides. The personnel in Operation Department has to complete a training programme before their assignment to safety related duties.

Operation Support Team conducts Initial, Continuing and Refresher Training. Even though the Final Safety Analysis Report commitment to NSSC requires only minimum 50 hours to obtain the operator licence, a typical operator undergoes an average of 152 hours of training, including 70 hours on Full Scope Simulator.

The training scope covers Operating Experience, Radiation Protection, Fire protection, Human Performance through the Korea Human Performance Enhancement System. The Training programme is generally completed in 6 months. The 76 hours are organized around 15 specific subjects and delivered through 4 categories (FSS - Full scope simulator, Lecturer, Discussion and Others). As an example for the 6 first months of 2012, the EM team recognized 35 on FSS, 8 hours for discussion about abnormal and emergency situation, 6 hours of lecturer about Global Education, including Nuclear Safety lecturer by the Plant Manager, and 4 hours of lecturer about Reduction of Core Damage.

WANO SOER 2010-01-09, concerning Safety during Shutdown, has been presented to Operation on June 5th. All the participants signed the Completion Action and the Implementation of the recommendation 6 about protection equipment. The use of Human Performance tools is scheduled for June 15th.

The Shift Manager attends the training with his shift. Kori site has 3 full scope simulators. One of them is dedicated to Unit 1. In case of return after an extended absence, a qualified operator works for a month as a shadow member of a shift before being qualified again.

5.4. Accident Management Programme

The operating organization has established an accident management programme for the management of beyond design basis accidents.

After Fukushima, the five recommendations from INPO ER 11-11-2 and WANO SOER 10-1 have been reviewed on spent fuel pool cooling, pool temperature surveillance, updating of procedures, updating of Radiation emergency plan. For Operation, two procedures have been updated, Abnormal Operation Procedure and Spent Fuel Abnormal Procedure. Two other procedures have also been updated after Fukushima. Preventative Inspection against natural disaster (severe cold, severe hot, typhoon, earthquake) and the procedure against Tsunami. The training programme has factored these items into the training scope.

5.5. Operating procedures

The process established to generate and update the procedures is appropriate. For Normal operation, the Kori 1's operation department has 4 GOP, General Operation Procedures, covering all the different reactor modes from Refuelling, Cold Shutdown until Hot Full Power. The operators have 158 System Operation Procedures, 60 Alarm Procedures and 245 Test procedures. For abnormal operation, there are 63 procedures. For emergency, there are 41 Symptom Based Emergency Procedures.

The updating of the procedures is shared among the 6 operation shifts. The procedures are signed by the Plant Manager. For the Safety-Related procedures, the Plant Manager signed as chairman of the Plant Nuclear Safety Committee.

The temporary plant modifications are validated by the chairman of the Plant Health Committee, in a monthly meeting. The temporary plant modifications are monitored in the DREAMS computerised system and stored in a folder available in MCR. If there is a temporary modification, in MCR or in the field, operation staff attaches half of a red tag with references to the document. The other part of the red tag is fixed on the equipment concerned (push button, paper recorder, alarm in MCR, or sensor, relay, activator in the field). The

process was confirmed using the last temporary modification implemented on the main transformer work.

DETAILED OPERATIONS FINDINGS

5.1. Issue: Surveillance in the Main Control Room doesn't ensure that all important parameters are correctly reviewed during shift turnover.

The Standard Technical Administrative Procedure, "Operator turnover shift" presents the administrative controls and quality assurance which must be used by Operation. Section 6.1.1, requires that "each operator has to ask questions to outgoing operator when he has questions about operation status". Section 6.1.2, requires that "operators have to understand plant operation status by checking the log sheets and log books from the previous working day". Section 5.3.3, specifies that the Shift Manager has the responsibility to supervise that the turnover is conducted correctly.

The night shift during shift turnover from 23:30 to 24:00 on 9 February probably did not identify signs of the SBO event. The chart recorder of primary coolant hot leg temperature clearly recorded the temperature increase of about 20 C during 20:35–20:54 and a subsequent decrease to normal value in about 1.5 hours (the cold leg temperature increase was somewhat smaller). However the period visible on the paper chart until it folds (without opening the window of the recorder and unfolding the chart) is about 2 hours. The new shift is expected to review all chart recorders, following the requirement 6.1.2. A good practice, recognised and promoted by the Operation Department, is to draw a line, to indicate actual time and to sign this 'time stamp'. This time stamp was not entered by the night shift on the primary coolant temperature charts at 24:00 on 9 February. In fact, the previous time stamp was entered at 08:00 on 8 February.

If the night shift had strictly followed the requirement of the Standard Technical Administrative Procedure to review operational records on safety related systems since the last working day, they would have recognized the transient of primary coolant hot leg temperature which is a key safety parameter for a reactor in shutdown state. Similarly the record of "residual heat removal pump flow low" signal and the "residual heat removal pump tripped" signal would have been detected if the printout of the alarm printer was checked.

The Standard Technical Administrative Procedure, "Operation Record Management", presents the round sheets and shift operating practices". In Section 4.5.1 the time designated for required walk down are specified. 09:00 and 14:00 for the Day shift, 17:00 and 22:00 for the Afternoon shift, 01:00 and 06:00 for the Night shift. In 6.2.2, it is specified that during transient, shutdown or radiation emergency, the time for walk down could be changed or skipped with permission of the shift manager in advance. However some parameters required by Technical Specifications

must be recorded. The hot leg temperature is a one of the critical parameter during Cold Shutdown state.

A good questioning attitude, during the next handover and during the 4 walkdowns, would have identified an abnormal transient during the SBO event and the subsequent decision to change from Cold Shutdown to Defueling state.

Without continuous surveillance of the main nuclear-safety related parameters, a non-detected abnormal trend could increase the nuclear safety risk through the failure to implement appropriate corrective actions.

Recommendation: The plant should reinforce the requirement that all important parameters are correctly reviewed during shift turnover in the Main Control Room.

IAEA Basis:

SSR-2/2

7.9. The alarms in the main control room shall be managed as an important feature in operating a plant safely. The plant information system shall be such that off-normal conditions are easily recognizable by the operators. Control room alarms shall be clearly prioritized. The number of alarms, including alarm messages from process computers, shall be minimized for any analysed operational state, outage or accident condition of the plant. The operating organization shall establish procedures for operators to manage the response to alarms.

NS-G-2.14

4.16. All important information about the plant status, the work in progress and the plant evolutions in the previous shift should be transferred and documented properly in the course of the shift turnover. This information should include a joint check of systems in which the incoming and outgoing operators walk down the control panels and jointly read checklists, log books, records and messages to familiarize themselves adequately with the status of systems and equipment.

5.2. Issue: The operation department, responsible for nuclear safety, doesn't adequately challenge the work scheduling decisions concerning some activities approved during the daily meeting.

The Daily meeting is chaired by the Plant Manager and is very well organised. However there is no great challenge from the Operation department on the information given by the senior managers.

On the June 7th, nearly 100 works or tests were approved for the Unit 1 and 2. In the document which lists the different activities scheduled, each of them is affected by a colour White, Yellow or Red, and by a code Y or N. Yellow means that the activity could have an impact on the availability of a system or equipment. Red means that the activity could create trip, transient etc. Y, for Yes, means that the activity could present a risk of shutdown, or cause a transient or enter a new condition in Technical Specifications. Generally an activity

classified Y is also highlighted Red. The activity 40376817 was the change of a filter on the injection line of the seal 1 of one of the Primary Pump Unit2, at full power. This activity was not classified Y. No activities were classified Y.

More generally, the exam of the Daily meetings of May 30th to 8th June reveals that for 7 daily meetings, and for 505 activities approved (CM – minor maintenance, PM – preventative maintenance and ST- surveillance test) 17 has been highlighted Yellow (3%) and 10 Red and Yes (2%).

The lack of challenging and questioning during the daily meeting of work scheduling decisions doesn't allow the shift to implement the right level of control.

Suggestion: The plant should consider encouraging the Operation Departement to enhance the internal control of activities and to be more challenging and questioning during the daily meeting.

IAEA Basis:

SSR 2.2

8.22. The interfaces between the group responsible for outages and other groups, including groups on the site and off the site, shall be clearly defined. Operating personnel shall be kept informed of current activities for maintenance, modification and testing.

NS-G-2.14

2.26. The interface between the operations department and the maintenance department should be established in particular for all aspects of outage activity, to ensure that risk from an outage is managed properly and the effectiveness of an outage is maximized. This should be achieved by means of thorough planning and scheduling, effective coordination and implementation and the timely return of systems and components to safe operational status.

7.18. The operations department should be involved in all aspects of activities in outages to ensure that the risks in outages are managed properly and the effectiveness of outages is optimized by thorough planning and scheduling, effective coordination and implementation and the timely return of systems and components to operational status.

6. MAINTENANCE

6.1. Maintenance organization

The organization of the maintenance department is logical and should as such not pose a problem for an efficient operation. However, the whole maintenance organization (including maintenance engineering) consist of 130 persons from KHNP, while the number of permanent contractors working in the same organization amounts to 220. Looking at the 'core' teams, being mechanical, electrical and I&C maintenance, there are 61 KHNP staff and 190 contractors. This is a ratio of over 1:3, which is high. This underlines the importance of an efficient training and qualification program for the contractors, as well as clearly defined responsibilities of all involved.

6.2. Qualification and training of personnel

A training programme is established and maintained for the training of personnel before their assignment to safety related duties. The training programme also includes refresher training on a regular basis (mostly yearly). The content of the training programmes is based on a systematic approach to training, and includes training on radiation protection, industrial safety, nuclear safety, human performance, etc.

Training is provided to KHNP staff and to contractors. Permanent contractors receive a full initial and refresher training, while non-permanent contractors receive a limited training, focused on radiation protection and industrial safety. For the non-permanent contractors, supplementary training is provided in function of the work they will execute at the plant. For example, the contractors that performed the test that led to the SBO event had received extra training on HP tools and plants power supply systems.

Technical training is also provided for KHNP staff and contractors. The maintenance field simulator is of high quality. The simulated RCA environment, including a large-scale simulated pool with reactor vessel, reactor head, fuel element dummies and the refueling machine are indications of good performance.

However, the contractor's training, procedures and supervision does not ensure the adequacy of attention to detail in safety related activities.

For example, the human performance tools used at the maintenance field simulator for the contractors do not correspond completely to those of the KHNP staff. Also, the quality of the contractor's training is reviewed independently by KHNP but not when subsidiaries of KHNP are concerned. The team has made a suggestion in this area.

A qualification program for KHNP staff and contractors is in place. The basic technical qualifications (professional degree) for the contractors are imposed via the contract and are sent to a dedicated KHNP maintenance service for follow up.

6.3. Material conditions and housekeeping

The housekeeping of the plant is good. The overall plant material condition is good. However, some material condition deficiencies were found in the installation. The team has a suggestion in this area.

6.4. Maintenance, testing, surveillance and inspection programmes

The surveillance program strategy is well described in procedure STAP-STM02 ‘Surveillance program’, listing the responsibilities of the different departments. The different surveillance tests for the plant are described in procedure 01635r00, including those to be performed by operations and the three maintenance teams. A check showed that the tests to be performed on the diesel engines (procedure 1-9-123) is ok. The tasks to be performed by the different departments are clearly described in this procedure.

The preventive and predictive maintenance programs are described in procedure STAP-MEM-15 and STAP-MEM-16. A check in the ERP system (SAP) showed that the defined maintenance plans are present in the system, and triggered for execution as PM01 orders (daily operations) or PM02 orders (outage), according to their maintenance frequency.

However, there are a few indications that the preventive maintenance program for certain solenoid valves is not complete :

- the solenoid valves of the diesel air supply system (DG-VEE11B and DG-VEE11A) are preventively tested and measured every year by I&C maintenance team. In case of an anomalie, the valve was replaced. Because the maximum life time is not stated in the manufacturers available documentation, the preventive maintenance does not foresee in a scheduled replacement. The solenoid valve on diesel B was last replaced in 2012 (after the SBO incident) and the one of diesel A is planned to be replaced this year.
- three events are mentioned in the list of event reports of 2009-2011 in the AIP that are due to malfunctions of solenoid valves and/or actuators : broken joint neck of an actuator (K01-09-016-OP), delayed closing time of check valve (K01-09-025-OP) and malfunction of IA compressor supply solenoid valve (K01-11-041-OP).

A review and possible completion of the preventive maintenance program of these solenoid valves is encouraged.

6.5. Work planning and control system

There is a comprehensive work planning and control system that ensures that work for purposes of maintenance, testing, surveillance and inspection is properly authorized and carried out safely. The initial work order approval is given by the maintenance supervisor

after review and preparation of the work. The final work permit is given by Operations, after securing the equipment. The work permit is to be collected at the control room. Based on the defined importance level, work permits can be collected at the control room by the KHNP supervisor or the contractor's field chief.

The importance of work orders is based on different criteria (FSAR, FID,...), that are linked with the corresponding functional location, and the work control system automatically proposes an importance level. The maintenance supervisor checks this proposal, taking also into account the actual nature of the work (cleaning, overhauling, calibrating,...) and assigns the final importance level.

Good co-ordination between the different maintenance teams is enhanced through the daily meeting at 8h15 with the director general, his deputies, senior KHNP managers and contractor managers, as well as during the daily meeting at 9h00 between the deputy director of maintenance and his direct reports.

For each work, a pre-job briefing is given using a template. The exact starting time of this pre-job is mentioned in the list of works that is given to Operations at day N-1 for preparing and securing the works for the next day. This is a good performance. The pre-job briefing is attended by the supervisor and all the workers involved (KHNP and contractors). Everybody has to sign the pre-job form.

A post-job briefing is also held, called post-job critique, using a specific form.

A check of the work preparation package of the inspection and cleaning of a CC heat exchanger showed a good quality of this package, that included the corresponding maintenance procedure, pre-job, post-job briefing and other relevant documents.

6.6. Outage management

There is an effective outage planning process in place. The process starts one year before the outage, with the determination of the initial scope and then proceeds in a logical way according to different milestones. The planning is set up in blocks of works, maintaining the plant configuration in accordance with the operational limits and conditions.

The draft planning is made by the maintenance planning team, based on the experience from the past (integrated in the planning system), and checked by operations and the departments involved.

All remarks are collected by the maintenance planning team, and the updated version of the planning is sent to operations for independent control.

There was until recently no check, by a department independent from operations and maintenance, of the safety related part of the final planning (core cooling, reactivity control, sources of power supply, containment integrity, cold source, etc.). This is now in place and will be used for the next outages of Kori unit 1 by the Safety and Engineering Support team.

However, the process to reschedule electrical related activities during the outage has weaknesses. The team has made a suggestion in this area.

DETAILED MAINTENANCE FINDINGS

6.1. Issue: In certain plant areas inadequate conditions exist due to lack of attention and imperfections in maintenance work execution. Although the overall plant material condition is good, the team found examples where improvements are still needed to maintain consistent high standards, in the following areas:

Mechanical works:

- Washers are present between the bolts on the pipe flanges near the spray pump B (XPP-43B), but there are no washers between the bolts on the pipe flanges near the spray pump A (XPP-43A). This is inconsistent.
- The bolts of several stainless flanges of the IA system show corrosion at the surface, due to use of carbon bolts. Moreover, no washers are used.
- The hoisting hook near pump XPP-42A is not properly fixed to the wall because the nuts were not tightened
- There is some rust, loose paint and dust around the spindles of several valves that make the connection between the pump lines and the measurement systems of AFW pump B

Electrical and I&C works:

- Two rosemount transmitters in a safety related application were found with shipping caps that should have been replaced with stainless steel plugs. Five rosemount transmitters had side caps that were not torqued correctly.
- The rubber cover of the manual button of the solenoid valve of the diesel B air supply system was not replaced after maintenance (it was lost). Instead a plastic cap was placed over the top of the solenoid. This may have contributed to the blockage of the plunger in its guide tube due to intrusion of dust/other particles, which led to the failed start of diesel B during the SBO event of Feb. 9.
- The circumferential sealing rubber of the local differential pressure indicator of the main reactor building hatch is not correctly placed
- The protection grounding on junction box TB VS1-8805A and at the basis of pump XPP-96B are loosely connected
- Some important instrumentation lines around the diesel engine A (e.g. for oil temperature) are not firmly attached to a fixed structure (pipe, floor, cable tray). The risk of damaging these lines when doing field tours or other inspections is not negligible.

Lifting devices:

- The lifting device near spray pump A (XPP-43A) and SI pump A (XPP-42A) are not blocked to prevent their movement during a seismic event.

Deficient material conditions, if left unattended, could lead to deterioration of the equipment and systems at the plant.

Suggestion: The plant should consider eliminating inadequate conditions existing in certain plant areas due to lack of attention and imperfections in maintenance work execution, focusing on the bolts/nuts and the transmitters.

IAEA Basis:

SSR-2/2

7.10. Administrative controls shall be established to ensure that operational premises and equipment are maintained, well lit and accessible, and that temporary storage is controlled and limited. Equipment that is degraded (owing to leaks, corrosion spots, loose parts or damaged thermal insulation, for example) shall be identified, reported and corrected in a timely manner.

6.2. Issue: The process to guarantee the correct plant configuration, in accordance with the operational limits and conditions, when rescheduling safety related electrical activities during an outage has weaknesses.

- The works for the station auxiliary transformer A (SAT A), station auxiliary transformer B (SAT B) and unit auxiliary transformers A and B (UAT A/UAT B) were initially correctly planned in three different serial blocks, but a work in block UAT A/UAT B, namely a protective relay test, was replaced from this block to a period that corresponded with this of block SAT A. This rescheduling decision did not arrive at the level of the OCC (Outage Control Center).
- The works for the station auxiliary transformer A (SAT A), station auxiliary transformer B (SAT B) and unit auxiliary transformers A and B (UAT A/UAT B) were initially correctly planned in three different serial blocks, but block SAT B was started before the SAT A was fully requalified. This deviation of the planning was not raised to the OCC (Outage Control Center), mainly because the SAT A and SAT B transformers were not defined as safety related in the outage rescheduling.
- Both facts, combined with the human error during the protective relay test, led to the SBO event

An incomplete process for controlling and maintaining correct plant configuration when rescheduling safety related electrical activities during an outage, can lead to lack of sources of power supply, loss of core cooling, or other unwanted unavailabilities.

Suggestion: The plant should consider reviewing and reinforcing its process for controlling and maintaining correct plant configuration when rescheduling safety related electrical activities during an outage.

IAEA Basis:

SSR-2/2

8.19. In the processes for planning and performing outage activities, priority shall be given to safety related considerations. Special attention shall be given to maintaining the plant configuration in accordance with the operational limits and conditions

8.22. The interfaces between the group responsible for outages and other groups, including groups on the site and off the site, shall be clearly defined. Operating personnel shall be kept informed of current activities for maintenance, modification and testing

6.3. Issue: Contractor's training, procedures and supervision does not ensure the adequacy of attention to detail in safety related activities.

- Scarcity of contractors qualified for test of generator protection system – this was the reason for rescheduling the test, because of time pressure for the contractors to move to next work site
- Human error: supervisor instructed “do not proceed to next step”, contractor worker disregarded the order and proceeded and activated next channel during generator protection test
- Human factor: overconfidence of contractor worker due to long experience with this test
- Procedure: preconditions, potential risk and consequence of error not described; no requirement to sign off completed steps in the generator protective relay test procedures
- Contracting companies are responsible for all parts of training for their staff, including radiation protection and nuclear safety. The operating organization checks that relevant courses have been taken. The quality of the training is reviewed independently by KHNP, however not when subsidiaries of KHNP are concerned.
- The human performance tools used at the maintenance field simulator for the contractors do not correspond completely to those of the KHNP staff.
- The team conducted a walk down of the radiation controlled area to observe the condition of electrical and instrumentation that are critical to plant safety. The team observed two Rosemount transmitters PT-4832 and PT-4830 having maintenance attributes not adequately implemented. Certain models of transmitters are equipped with two access ports for making electrical connections. The unused secondary port is required to be closed with a stainless steel plug after removing the orange coloured

plastic cap that is inserted to keep the internals clean. Additionally the two side caps provided for access into the internals of the instrument have to be sealed with a new “O” ring and torqued to a specific value for protection against anticipated harsh environment. The I&C management indicated that the inconsistency has resulted from the contracted work that used different procedures for a narrow population of transmitters. The absence of inadequate environment sealing negatively influences the accuracy of pressure transmitters in accident environment and that could lead to setpoint drift for automatic actions and inaccurate indications on displays.

Without adequate training and supervision of contractor’s quality of work performed by them may not be fully ensured.

Suggestion: The KHNP maintenance management should consider conducting a review of contractor’s training, procedures and supervision to ensure the adequacy of attention to detail in safety related activities.

IAEA Basis:

SSR-2/2

4.20. Performance based programmes for initial and continuing training shall be developed and put in place for each major group of personnel (including, if necessary, external support organizations, including contractors). The content of each programme shall be based on a systematic approach. Training programmes shall promote attitudes that help to ensure that safety issues receive the attention that they warrant.

6.12. The operating organization shall ensure that interfaces and the communication lines between different groups (i.e. groups for design, for construction, contractors, for commissioning and for operations) shall be clearly specified and controlled.

NS-G-2.6

3.8. Contractors should be subject to the same standards as plant staff, particularly in the areas of professional competence, adherence to procedures and evaluation of performance. Suitable steps should be taken to ensure that contractors conform to the technical standards and the safety culture of the operating organization.

3.9. Activities performed by contractors and other personnel who are not permanent employees of the plant should be controlled by means of established management systems. These systems should cover the training and qualification of contractor personnel, radiation protection, familiarity with and adherence to procedures, understanding of plant systems, and applicable administrative procedures for both normal operation and emergency conditions. Contractor personnel should be made aware of their responsibilities in relation to the safety of the plant and the equipment they maintain.

7. ELECTRICAL SYSTEMS

7.1. Emergency Diesel Generator (EDG) Failure to Start

The direct cause of the EDG B failure to start during the SBO event was from the failure of solenoid operated air-admission valve (SOV) to open in the air supply for cranking (rolling the engine) the EDG to start. The plunger in SOV was found have a scratch that indicated a chipped internal part or foreign material carried forward through the air system.

The EDG had two air compressors (one motor driven and other a diesel engine driven) providing air to one air storage tank, sized to supply enough air for 5 consecutive EDG starts, however, the system relied on one SOV for supplying air to start the engine. In response to the recent failure, KHNP has replaced the original valve with 2 new parallel SOVs of different type to prevent SOV's single failure vulnerability for EDG B. EDG A is scheduled to have the same modification completed by June 2012. A further design improvement to have a second air tank for each EDG is planned for next year to further enhance the possibility for a successful start.

7.2. Main Generator Protective System Test

The electrical maintenance work on Main Generator protective relaying was conducted by a contractor. The contractor's scope of work included development of the test procedure and execution of the test. KHNP provided administrative approval for conducting the test and provided supervision. This procedure required strict adherence to the steps and an omission could lead to loss of offsite power. This vulnerability was not recognized by the Main Control Room staff and this test had been historically viewed as a low risk electrical-led activity. The historical view was based on the test being conducted in a different electrical alignment that would not have resulted in interrupting an operating RHR pump. The selected shut down cooling loop during this electrical test and the lack of compliance to the test procedure and the instructions given collectively contributed to the SBO.

Kori unit 1 and 2 response to the event has resulted in upgrading the procedure to Kori unit 1 and 2 procedure with three signatures (performer, Lead/QA and Kori unit 1 and 2 test Supervisor) on each step to ensure strict adherence to the steps and prevent any undesirable results. Additionally, the prerequisite for conducting the test now involves ascertaining that the power supply to the shutdown cooling system and other plant systems do not rely on the associated breakers remaining closed.

This procedural weakness and the conduct of the test is an isolated case in light of the additional test procedures that were examined.

7.3. Emergency Declaration & Reporting /White Alert Condition

On February 9, 2012, during a refuelling outage, Kori Unit #1 experienced a station blackout. Based on the plant transient data report, the actual duration of the SBO condition was 11 min and 39 seconds. The shutdown cooling was interrupted for a period of 19 min. In light of the conflicting views on the promptness and the prudence in electing not to report, EM team conducted an independent assessment of the plant event.

The plant Radiation Emergency Plan has adopted NRC NUREG 0654/ FEMA-REP-1 Rev 1 for “Initiating Conditions: ALERT”. Criterion 7 on “Loss of offsite power and loss of all onsite AC power” is translated into a procedure in Korean vernacular. The Korean version is silent on the Reactor Mode of operation for assessing the radiation emergency but the US version has further elaborate guidance supplemented through NEI 99-01 Revision 5, that indicates that SBO ALERT applies to cold shut down and refueling condition only when its duration is 15 min or more. However, the NEI guidance is not applicable to Kori station and therefore a strict compliance to the procedure would have been to enter the white alert condition and process the required reports.

A vocal report to the regulator was not done in the required 4 hours in light of the Plant manager’s executive decision not to make any reports of the SBO event. The operators and staff members in the control room assumed the traditional practice of honouring the manager’s decision.

The 60 day written report was completed on April 9, 2012

7.4. Shutdown Risk

Kori Unit 1 station is upgrading the risk assessment capability using the state of the art technology. A trial version of this program was used in Kori unit 2 during the last refueling outage. This program is structured to identify problem areas that negatively impact nuclear safety. The program has the capability to address: reactivity control, Core management, Residual heat removal, containment integrity, and heat removal of spent fuel. The plant shut down work can be entered for assessing the risk exposure that could be displayed in Red/orange/amber/green based on the level of risk. The shutdown risk assessment capability will be fully operational for Kori-Unit 1 by next refueling outage.

7.5. Onsite Power System

The onsite power system consists of two trains of class 1E buses at 4.160 kV with each one sized to mitigate a large break LOCA. Each of the safety buses are designed to be energized from one of the offsite power sources and from the respective EDGs with fuel capability for 7 days. The breaker alignment includes provisions to cross connect the trains manually under emergency conditions.

7.6. Offsite Power System

The offsite power for the Kori-1 station is currently from a substation that is about 8.4 meters from mean seal level (MSL). This substation will be phased out and a new one is being built at about 75 m from MSL in response to the Fukushima actions with the capability to withstand design basis earthquake. The new 345 kV substation will have 12 nuclear stations feeding and six other nuclear stations connected from 65 km away. A configuration of this structure with power sources from distant locations increases the potential for increased availability under localized external events.

The grid operators has committed adequate spinning reserve to accommodate the trip of the largest nuclear station and still provide adequate voltage and capacity to support normal or emergency shutdown of the affected plant.

KHNP has entered into an agreement with the local power transmission grid operators for ensuring reliable offsite power for responding to normal and emergency shutdown. The electrical switchyard is physically located in the nuclear plant controlled area and therefore, the maintenance activities will have to be coordinated through the expressed approval nuclear station thus reducing unanticipated challenges to the stations. These agreements and the established operating procedures ensure reliable offsite power for supporting nuclear safety.

7.7. Electrical Maintenance/Aging Management

The maintenance engineering for electrical department has a program in place for ensuring availability of electrical equipment. The program monitors equipment manufacturer's specified service life, performance of the equipment in meeting the plant specifications, and loss of technical support to obsolescence. The program includes management of subcomponents in case of large equipment. The program was successful in monitoring the safety grade plant batteries and implementing the replacement before its performance could become questionable. The performance indication is observed as a primary indicator for confirming the operability of the equipment. This approach has resulted in early replacement of certain equipment well ahead of any potential concerns on operability or availability of equipment.

A dedicated task force focuses on major replacement components such as reactor vessel head, steam generator, etc., that require significant lead time for production, major funding and

coordination to implement. This approach is commendable in that it relieves the plant maintenance staff to focus on minor issues that are manageable in a short term schedule.

DETAILED ELECTRICAL SYSTEM FINDINGS

7.1. Issue: The alternate AC (AAC) power system has fuel reserve only for 8 hour to support Kori units 1-4.

AAC power supply is available onsite is designed to support all the 4 units during the remote possibility of losing all other onsite AC sources for the respective units. The capacity exceeds the combined electrical load of two trains of safety buses at Kori Unit 1. The design includes provisions to connect the AAC to any of the safety buses. The AAC is designed as an independent structure with dedicated battery and air system. The electrical power for charging the dedicated battery, air start system, and keep warm systems for its standby condition could be aligned to any of the units. The output of this generator is the same voltage as the safety bus.

The current design basis for the operational duration is 8 hours. In light of the geographical proximity to an ocean with possibility for typhoons and storms, and the necessity to support 4 nuclear units, the onsite fuel for 8 hours at full capacity meets only minimum requirements.

Without sufficient fuel reserve the continued operation of the AAC power supply until external support becomes available cannot be ensured.

Suggestion: The plant should consider providing additional onsite fuel capability for responding to emergencies when access to fuel suppliers could be limited.

IAEA Basis:

NS-G-1.8

4.73. The boundaries of the non-electrical equipment on the input side include storage reservoirs of sufficient capacity as to be capable of providing the necessary ‘fuel’ (e.g. pressurized nitrogen or air, fuel oil) to the prime mover for the time period specified in the design requirements for the plant.

8. OPERATING EXPERIENCE

8.1. Feedback of operational experience

The plant has developed and introduced a system for operating experience feedback that comprises basic elements such as identification and reporting of events, screening, investigation and analysis, implementation of corrective actions and assessment of its effectiveness. The plant has allocated sufficient resources to manage operating experience and corrective actions programme including dedicated representatives from departments and groups. The plant receives support from the utility (KHNP) and its technical support organization (Central Research Institute). Plant activities in the area of operating experience feedback are supported with several effective computerised tools that are used to handle in-house and external operating experience. These computerised tools are shared by all KHNP nuclear power plants that facilitate exchange of operating experience data internal and external. The plant has established a policy and procedures that cover activities related to operating experience feedback.

According to the plant policy significant events, minor events, low-level events, near miss and potential problems should be identified and reported, including equipment failure, human performance problems, procedure deficiencies and documentation inconsistencies. However recent developments at Kori unit 1 and 2 have demonstrated that the performance in this area does not fit expectations that are reflected in the plant's policies and procedures. Several safety significant events that have taken place at Kori unit 1 and 2 recently have not been reported and managed appropriately by the plant's personnel and thus several plant's regulations and procedures have been violated.

Plant's corrective actions program (CAP) covers attributes related to investigation and analysis of events, development and implementation of respective corrective actions to remedy root causes and contributing causes to the events. It also focuses on assessment of effectiveness of corrective actions to prove appropriateness of actions taken in response to identified causes. CAP procedures specify a process for event investigation and analysis, corrective actions development and implementation including specific timetable for completion individual stages and the whole activity in general. Nevertheless the plant does not follow these procedures strictly having considerable delays in collection event related data, identification of root cause analysis and respective development and implementation of corrective actions. These delays lead the plant to be at risk during extended periods of time.

Kori-1 Station Blackout (SBO) event that happened 2012.02.09 and identified at CAP meeting as Class 1 event is considerably delayed with investigation and analysis. CAP notice and respective CAP registration has been issued on 25 May, 2012 (starting point for a Root Cause Analysis type of investigation), 2.5 month after the event was declared on 2012.03.12.

EDG-B failed during a pre-operational test after modification (dualization of air supply system with new solenoid valves) on 2012.05.17. Direct cause has been identified as –

electronic surge in STOP relay. Temporary modification has been made and implemented within one week on 2012.05.23; however RCA investigation process has not finished yet and target date does not meet plant procedures requirements.

During daily CAP meetings the plant uses criteria for classification of events on safety significance. However these criteria are not specific and handled arbitrarily with no specified method that leads to a potential of incorrect grading of events. The EDG-B failure on 2012.02.26 was incorrectly classified at CAP meeting as Class 3 event (event with no safety implications). Subsequent handling of the event did not correspond to the severity of a case. Operating Experience report, Detailed Operating Experience Report (report to KINS), Root Cause Analysis (RCA) report have not been performed.

The Kori plant has already introduced some corrective actions prescribed by Nuclear Safety and Security Commission (NSSC) in response to SBO event, at the time as root cause and contributing causes have not been identified yet. Delay with investigation and analysis of the significant event with safety implications keeps the plant at risk of repeat event as extend of conditions (procedures, practices, behaviours, other plant systems and equipment etc) have not currently determined and eliminated.

There are 22 plant's employees which received RCA training during the course of there activities at the plant and average two-three RCAs are performed during a year. However there is no requirement at the plant that RCA analysts receive periodic refresher training in this area. Also RCA team doesn't include qualified expert in the area of human and organizational factor.

During SBO event on 2012.02.09 "Situation Team" was not formed and "Situation log" was not filled with prompt data as required by plant's procedures. Collection of data related to the event has started much later and would cause complications in the course of event investigation.

DETAILED OPERATING EXPERIENCE FINDINGS

8.1. Issue: The plant's reporting practice of significant events does not enable to initiate required prompt actions to manage an event, the plant conditions and mitigate consequences and does not comply with regulatory requirements, administrative and operating procedures.

- Station Blackout (SBO) event on 2012.02.09 was not identified and reported as per regulatory requirements and plant's administrative procedures.
- Violation of plant's Technical Specification chapter related to the lack of shift actions to immediately start taking action to restore EDG to operable condition
- Violation of plant's Technical Specification chapter [3.8.2] after Station Blackout (SBO) event (change the plant's state from mode 5 to mode 6 and start fuel movement, and maintenance activities with two inoperable Diesel Generators) has not been identified, reported and managed as per regulatory requirements and plant administrative procedures.
- The plant did not declare emergency action level according to the emergency plan after SBO event on 2012.02.09

Failure to timely identify and report significant events lacks opportunity to learn lessons and causes potential event recurring in-house and in the industry.

Recommendation: The plant should reinforce its event reporting policy and practices to ensure that significant events are reported promptly and required actions to manage an event, the plant conditions and mitigate consequences comply with regulatory requirements, administrative and operating procedures.

IAEA Basis:

No. SSR-2/2

Requirement 24: Feedback of operational experience

5.27. The operating organization shall establish and implement a programme to report, collect, screen, analyse, trend, document and communicate operational experience at the plant in a systematic way. It shall obtain and evaluate information on relevant operational experience at other nuclear installations to draw lessons for its own operations. It shall also encourage the exchange of experience in national and international systems for the feedback of operational experience. Relevant lessons from other industries shall also be taken into consideration as necessary.

NS-G-2.11

10.4. Operating experience should be reported in a timely manner to facilitate learning from events. To this end operating organizations should put in place the necessary arrangements to ensure that all events that occur during operation of the plant are systematically reported and analysed.

10.8. The key criteria for events that should be reported to the regulatory body should include the following

...

(2) An operation or condition prohibited by the operational limits and conditions;

(3) Any event or abnormal condition that resulted in the condition of the nuclear installation, including its principal safety barriers, being seriously degraded;

...

(6) Any event in which a single cause or condition caused a significant loss of operability in a safety system;

...

(9) Declaration of an emergency condition as specified in the emergency plan;

...

(11) Any safety significant event during shutdown or refuelling (e.g. the dropping of a fuel assembly);

10.9. The operating organization should develop detailed procedures for the reporting of events. Such procedures should ensure that events of major safety significance are communicated promptly to the appropriate organizations, both internally (on the site) and externally to the utility's headquarters, the regulatory body and any other relevant organization.

NS-G-2.4

6.68. All plant personnel should be encouraged to report all events and near misses relevant to the safety of the plant. All plant personnel should be given the opportunity to report all events and near misses. It is the responsibility of plant management to review and respond to these submissions in a timely and confidential manner.

8.2 Issue: The plant Corrective Actions Programme (CAP) is not robust to ensure that significant events are handled appropriately and effectively, lessons are learned and respective corrective actions are implemented timely to prevent repeat events.

- Kori Station Blackout (SBO) event (identified at CAP meeting as Class 1) is considerably delayed with investigation and analysis. CAP notice and respective CAP registration has been issued on 25 May, 2012 (starting point for a Root Cause Analysis type of investigation), 2.5 month after the event was declared.
- EDG-B failure during performance test on 2012.03.15 has not been handled according CAP procedures. Dead line for RCA completion 2012.05.18 has not been met.
- EDG-B failed during a pre-operational test after modification (duplication of air supply system with new solenoid valves) on 2012.05.17. Direct cause has been identified as – electronic surge in STOP relay. Temporary modification has been made and implemented within one week on 2012.05.23; however RCA investigation process has not been finished yet and target date does not meet plant procedures requirements.
- The event classification criteria are not specific and are interpreted arbitrarily. The EDG-B failure on 2012.02.26 was incorrectly classified at CAP meeting as Class 3 event (event with no safety implications). Subsequent handling of the event did not correspond to the severity of a case. Operating Experience report, Detailed Operating Experience Report (report to KINS), Root Cause Analysis (RCA) report have not been performed.
- EDG-B failed during a pre-operational test after modification (dualization of air supply system – new solenoid valves) on 2012.05.17. Classification has not been done next day during daily CAP meeting on 2012.05.18, only on Monday 2012.05.21. this caused delay in starting RCA analysis.
- During SBO event on 2012.02.09 “Situation Team” was not formed and “Situation log” was not filled with prompt data. Event data collection started much later.
- Currently 87 corrective actions are overdue in implementation amongst the 211 active corrective actions.
- RCA team does not include qualified Human and Organizational Factor specialist.
- There is no requirements for maintaining proficiency of RCA analysts (refresher training)
- WANO SOERs 1999-1 and 2002-2 have been analysed and respective action plan implemented during 2004-2005 period. However currently plant key personnel (control room operators, engineering and maintenance personnel etc.) do not have any related refresher training related to SOERs in there training programmes.

Failure to maintain effective CAP programme causes deficiencies in RCA investigation and analysis process and in turn negatively affects implementation of corrective actions to remedy root causes, contributing causes and prevent repeat events.

Recommendation: The plant should enhance its CAP programme to ensure that significant events are handled appropriately and effectively, lessons are learned and respective corrective actions are implemented timely to prevent repeat events.

IAEA Basis

No. SSR-2/2

Requirement 24: Feedback of operational experience

5.28. Events with safety implications shall be investigated in accordance with their actual or potential significance. Events with significant implications for safety shall be investigated to identify their direct and root causes, including causes relating to equipment design, operation, maintenance or human and organizational factors. The results of such analyses shall be included as appropriate in relevant training programmes and shall be used in reviewing procedures and instructions. Plant event reports and non-radiation-related accident reports shall identify tasks for which inadequate training may be contributing to equipment damage, excessive unavailability of equipment, the need for unscheduled maintenance work, the need for repetition of work, unsafe practices or lack of adherence to approved procedures [1].

5.30. As a result of the investigation of events, clear recommendations shall be developed for the responsible managers, who shall take appropriate corrective action in due time to avoid any recurrence of the events. Corrective actions shall be prioritized, scheduled, and effectively implemented and shall be reviewed for their effectiveness. Operating personnel shall be briefed on events of relevance and shall take the necessary corrective actions to make their recurrence less likely.

NS-G-2.11

5.2. The development of recommended corrective actions following an event investigation should be directed towards the root causes and the contributory causes, and should be aimed at strengthening the weakened or breached barriers that failed to prevent the event. Personnel at nuclear installations are responsible for implementing corrective actions promptly and effectively. A sense of personal interest or ‘ownership’ should be promoted by involving the members of the organization’s event investigation team in formulating the corrective actions to be recommended.

ATTACHMENT: PRELIMINARY IRS REPORT

**Kori
Nuclear Power Site
Unit 1**

IAEA IRS Kori 1 SBO

Title: Loss of shutdown cooling due to station blackout during refueling outage

Date of Event: February 09, 2012

Plant Name: Kori Unit-1

Commercial Operation: April 29, 1978

Designer: Westinghouse 2 loop, PWR

ABSTRACT

On February 9, 2012, during a refueling outage, loss of off-site power (LOOP) occurred and emergency diesel generator (EDG) 'B' failed to start while EDG 'A' was out of service for scheduled maintenance, resulting in a station blackout (SBO). Off-site power was restored 12 minutes after the SBO condition began. The LOOP was caused by a human error during a protective relay test of the main generator. The EDG 'B' failing to start was caused by the failure of the EDG air start system. Further investigation revealed that the utility did not exercise proper control of electrical distribution configuration to ensure the availability of the Station Auxiliary Transformer (SAT) while conducting test on the Unit Auxiliary Transformer (UAT).

After restoring off-site power through the SAT, the operators eventually recovered shutdown cooling by restoring power to a residual heat removal pump. During the loss of shutdown cooling for 19 minutes, the reactor coolant maximum temperature in the hot leg increased from 37 C to 58.3 C (approximately 21.3 C rise), and the spent fuel pool temperature slightly increased from 21 C to 21.5 C.

There was no adverse effect on the plant safety as a result of this event, no radiation exposure to the workers, and no release of radioactive materials to the environment. However, inconsistent with the requirements, the licensee did not report the SBO event to the regulatory body in a timely manner and did not declare the "alert" status of the event in accordance with the plant emergency plan. The licensee reported this event to the regulatory body about a month after the event had occurred.

Narrative Description

On February 9, 2012, during the refueling outage, the reactor vessel head was removed and flooded with borated water at refueling cavity. The fuel transfer from reactor pressure vessel to spent fuel pool was under preparation. Shutdown cooling was being provided by the residual heat removal (RHR) pump 'B'. The RHR pump 'A' was under maintenance. While the 4.16kV safety bus 'A' was not available as it was under maintenance, 4.16kV safety bus 'B' was energized from 345kV off-site power through the unit auxiliary transformer (UAT) 'B'. The station auxiliary transformer (SAT) 'B' and EDG 'A' were out of service for maintenance. The maintenance for SAT 'A' was completed and the breaker was left open at that time. So the available power sources, at that time, were one 345kV off-site power connected to the UAT 'B', and EDG 'B', which met the required power source configuration for the refueling modes of the plant technical specification.

The LOOP was caused by human error during the protective relay test of the main generator, and the subsequent SBO was due to the startup failure of the 'EDG B' caused by functional degradation, i.e the mechanical damage on the solenoid valve of the startup air system, of the startup air system of the EDG.

The SBO led the loss of RCS shutdown cooling and spent fuel pool cooling. In response to the SBO, the MCR operators restored the electrical power by connecting to SAT 'A' rather than to AAC DG (in stand-by state and in arrangement with Kori Unit-4), and subsequently restored the power supply to

the RHR pump 'B' in accordance with the procedure by establishing cross-tie of 480V bus 'A' with 480 bus 'B' because RHR 'A' was under maintenance.

The shutdown cooling was lost for 19 minutes. As a result of the event, the reactor coolant maximum temperature in the hot leg increased from 37°C to 58.3°C (approximately 21.3°C increase) and the temperature of spent fuel pool was increased slightly from 21°C to 21.5°C. No fuel damage was identified based on RCS I-131 activity analysis and thermal hydraulic audit calculation by regulatory investigation team.

There was no adverse effect on the plant safety due to this event. There was no radiation exposure to the workers or release of radioactive materials to the environment.

However, this event was not reported, intentionally, to the regulatory body in a timely manner at that time. In addition, this event met the condition of 'Alert' declaration in accordance with the emergency plan; nevertheless, the Alert was not declared. The licensee reported the event to the regulatory body about a month after the event had occurred.

As soon as the event occurrence was reported, regulatory body ordered the reactor shutdown, made the event public, and dispatched immediately the regulatory special inspection team to investigate the event. The followings are the plant behavior including the operator counter-actions in time sequence.

Feb. 4 2012

10:23

Control shutdown Reactor for refueling & overhaul

Feb. 5 2012

Started maintenance for EDG 'A' and SAT 'A'

Feb. 8 2012

Held pre-job briefing related to the relay test of generator

- Finished SAT 'A' maintenance, but incoming breaker left open
- Started SAT 'B' maintenance

Feb. 9 2012

19:30

Started protective relay test of GCB (Generator Circuit Breaker)

20:34:30

Occurred LOOP, low voltage on the safety Bus

- Opened automatically 345kV SWYD PCB 7100/7272

20:34:31

EDG B auto-start signal on

MCR operator found EDG 'B' fail to start

20:36

Failed to manual EDG 'B' start

20:40

Decided power restore using SAT 'A'

20:46:13

Closed breaker on SAT 'A' (SBO for 11min. 43sec)

20:52:41

Started Component Cooling Water pump

20:53:47

Started RHR pump 'B'

- Hot let temperature increased up to 58.3 C and decreased

20:53~21:30 <u>Feb. 10 2012</u>	Decided not to report (Plant staff including site manager)
13:00	Finished SAT 'B' maintenance
18:47	Started fuel transfer from reactor vessel to spent fuel pool
<u>Feb. 11 2012</u>	
22:00	Completed fuel transfer
<u>Feb. 12 2012</u>	
18:45	Finished EDG 'A' functional test (in standby mode)
<u>Feb. 13 2012</u>	
10:00	Started maintenance for EDG 'B'
<u>Feb. 22 2012</u>	
13:00	Finished EDG 'B' functional test (in standby mode)
<u>March 3 2012</u>	
	Reached reactor critical
<u>March 6 2012</u>	
	Reached 100% power after overhaul
<u>March 10 2012</u>	
	Reported SBO to newly appointed site manager
<u>March 11 2012</u>	
	Reported SBO to CEO of KHNP
<u>March 12 2012</u>	
	Reported SBO to NSSC
	NSSC ordered shutdown of Kori-1
22:00	started power decreasing for reactor shutdown
<u>March 13 2012</u>	
	Started special inspection by Regulatory Body (NSSC/KINS)
22:35	Shutdown reactor

Causes

The LOOP occurred due to human error. Although, during the testing of the protective relays of main generator, the test supervisor ordered the direction, "do not proceed to next step", upon the test trouble at channel 'A'. Test personnel preceded the test, while miss-understanding the supervisor's direction, channel B, creating the 2 out of 3 logic signals to actuate the circuit breakers in switchyard to open resulting in loss of 345kV off-site power grid and concomitant LOOP since 154kV off-site powers were unavailable.

Although EDG auto-start signal was on, EDG B failed to start caused by solenoid valve of the EDG air start system failure, i.e, mechanical damage, which resulted in SBO.

Through the regulatory investigation, it was also found that utility did not implement the LOV (loss of voltage) lessons-learned and commitment to exercise proper configuration control of electrical distribution by ensuring that SAT is available while conducting maintenance or test on UAT. This event emphasizes the need for careful planning and assessing the consequences of performing parallel maintenance and testing key equipment during reactor shutdown.

Additionally, many incorrect responses which were in violation of regulatory requirements were identified as follows; (1) Kori-1 plant manager and other major staffs decided not to record

LOOP and SBO in the main control room and did not report the event to regulatory body, NSSC/KINS, (2) They did not declare emergency action level in accordance with Kori-1 emergency plan, (3) utility staffs moved fuel while both EDGs were unavailable which was in violation of technical specification, and (4) EDG 'B' failure during a performance test subsequent to SBO event was not logged.

Safety Assessment

There was no radiation exposure to the workers or radioactive materials released to the environment. During loss of shutdown cooling for 19 minutes, the reactor coolant maximum temperature in the hot leg increased from 37°C to 58.3°C (approximately 21.3°C increase), the temperature of spent fuel pool increased slightly from 21°C to 21.5°C. No fuel damage was identified based on RCS I-131 activity analysis and thermal hydraulic audit calculation.

Corrective Actions

For the prevention of reoccurrence of the event, the following regulatory actions were ordered and/ or under implementation;

- Ordered shutdown of Kori 1 on March 12
- Opened event to the public on March 12
- Ordered verification of EDGs and AAC DGs operability for all NPPs (21 units)
- Reported and transferred investigation to the Government Prosecution Office
- Planning other enforcement actions

Lessons Learned

From a long-term point of view, for the prevention of reoccurrence and safe operation of the plant, special attention should be paid on the following lessons-learned;

- Reinforce regulatory oversight program to address safety culture
- Reinforce reporting requirements
- Reinforce EDG reliability requirements
- Reinforce configuration control and risk management during refueling outage
- Review test and maintenance procedures in depth
- Reinforce emergency action level declaration requirements and procedure

Summary

On February 9, 2012, during the refueling outage, Kori Unit-1 experienced LOOP and EDG failed to start due to human errors and mechanical failure, respectively, which resulted in SBO for a period of 12 minutes.

As a result of the event, during the loss of shutdown cooling for 19 minutes, the reactor coolant maximum temperature in the hot leg increased from 37 C to 58.3 C (approximately 21.3 C

increase), the temperature of spent fuel pool increased slightly from 21 C to 21.5 C. There was no adverse effect on the plant safety as a result of this event. There was no radiation exposure to the workers or release of radioactive materials to the environment.

However, this event was not reported, intentionally, to the regulatory body according to reporting requirements at that time. In addition, this event met the condition of Alert declaration in accordance with the emergency plan; nevertheless, the Alert was not declared. The licensee reported the event to the regulatory body about a month after the event had occurred.

IRS Coding

1. Reporting categories

- 1.2.5(Degradation of systems required to assure primary coolant inventory and core cooling)
- 1.4(Generic problems of safety interest)
- 1.6(Events of potential safety significance)

2. Plant status prior to the event

- 2.3.2.1(Refueling or open vessel - all or some fuel inside the core)
- 2.5(Testing or maintenance was being performed)

3. Failed/Affected system	4. Failed/Affected Component	5. Cause of the event
3.BE(Residual heat removal)	4.2.1(Pumps, compressors, fans)	5.1.2.7(Under voltage, voltage breakdown)
3.DA(Spent fuel pool or refueling pool cooling and cleanup)	4.2.1(Pumps, compressors, fans)	5.1.2.7(Under voltage, voltage breakdown)
	4.3.1(Switchyard equipment)	5.1.2.5(Circuit failure, open circuit)
3.EA(High voltage AC)	4.3.7(Relays, connectors, hand switches, push buttons, contacts)	5.1.10.2(Mistake) 5.3.5(Control of Contractor) 5.4.8(Routine testing with existing procedures/documents) 5.5.2.5(Questioning attitude, dealing with uncertainty) 5.5.9.2(Planning/ Preparation of work)
3.EF(Emergency power generation and auxiliaries)	4.2.3(Valve, valve operators, controllers, dampers and fire breakers, seals and packing)	5.1.1.9(Deformation, distortion, displacement, spurious movement, loosening, loose parts) 5.7.5(Equipment Aging)

6. Effects on operation

- 6.9(Outage extension)
- 6.10(Exceeding technical specification limits)

7. Characteristics of the incident

- 7.8(Failure or significant degradation of heat removal capability)
- 7.9(Loss of off-site power)
- 7.10(Loss of on-site power)
- 7.11.2(Temperature transient)

8. Nature of failure or error

- 8.2.1(Independent multiple failures or errors)

9. Nature of recovery actions

- 9.1.1(Recovery by foreseen human action)

9. LIST OF IAEA REFERENCES (BASIS)

Safety Standards

- **SF-1**; Fundamental Safety Principles (Safety Fundamentals)
- **SSR-2/2**; Safety of Nuclear Power Plants: Operation and Commissioning (Specific Safety Requirements)
- **NS-G-2.2**; Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants (Safety Guide)
- **NS-G-2.3**; Modifications to Nuclear Power Plants (Safety Guide)
- **NS-G-2.4**; The Operating Organization for Nuclear Power Plants (Safety Guide)
- **NS-G-2.6**; Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants (Safety Guide)
- **NS-G-2.8**; Recruitment, Qualification and Training of Personnel for Nuclear Power Plants (Safety Guide)
- **NS-G-2.10**; Periodic Safety Review of Nuclear Power Plants (Safety Guide)
- **NS-G-2.11**; A System for the Feedback of Experience from Events in Nuclear Installations (Safety Guide)
- **NS-G-2.12**; Ageing Management for Nuclear Power Plants (Safety Guide)
- **NS-G-2.14**; Conduct of Operations at Nuclear Power Plants (Safety Guide)
- **NS-G-2.15**; Severe Accident Management Programmes for Nuclear Power Plants Safety Guide (Safety Guide)
- **SSR-2/1**; Safety of Nuclear Power Plants: Design (Specific Safety Requirements)
- **NS-G-1.8**; Design of Emergency Power Systems for Nuclear Power Plants (Safety Guide)
- **GS-R-3**; The Management System for Facilities and Activities (Safety Requirements)
- **GS-G-2.1**; Arrangement for Preparedness for a Nuclear or Radiological Emergency (Safety Guide)
- **GS-G-3.1**; Application of the Management System for Facilities and Activities (Safety Guide)

- **GS-G-3.5;** The Management System for Nuclear Installations (Safety Guide)
- ***INSAG, Safety Report Series***
 - INSAG-4;** Safety Culture
 - INSAG-13;** Management of Operational Safety in Nuclear Power Plants
 - INSAG-15;** Key Practical Issues In Strengthening Safety Culture

Other

Root Cause Analysis Reference Manual – Draft IAEA TECDOC

IAEA Safety Glossary

Safety Reports Series 11 Developing safety Culture in a Nuclear Activities

OSART Safety Culture Assessment Guideline - draft

10. TEAM COMPOSITION OF THE EXPERT MISSION TO KORI I NPP

EXPERTS :

LIPAR Miroslav – IAEA

Years of Nuclear Experience: 35

Review area : Team Leader

VAMOS Gabor – IAEA

Years of Nuclear Experience: 35

Review area : Deputy Team Leader

PERSSON Göran - SWE

Years of Nuclear Experience: 28

Review area : Management Organization And Administration I

RYCRAFT Helen Sandra – UK

Years of Nuclear Experience: 37

Review area : Management Organization And Administration II

REYNAUD Michel - UK

Years of Nuclear Experience: 34

Review area : Operations

VAN BEVEREN, Koen – Belgium

Years of nuclear experience: 16

Review area : Maintenance I

KOSHY Thomas - IAEA

Years of Nuclear Experience: 35

Review area : Maintenance II

MARTYNENKO Yuri – IAEA

Years of nuclear experience: 27

Review area : Operating Experience