Development Strategy and Status of KHNP SOARCA Project

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2018 Regulatory Information Conference
Marriot Hotel & Conference Center, MD, USA
March 13-15, 2018

KHNP

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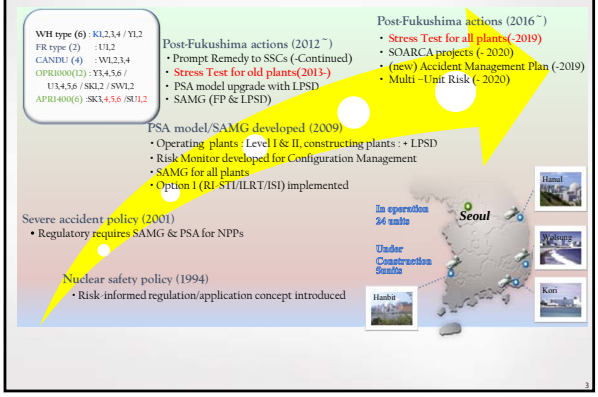
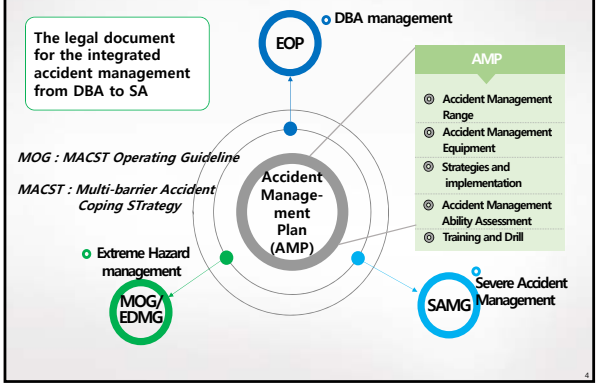
Background

KHNP



Accident Management Plan



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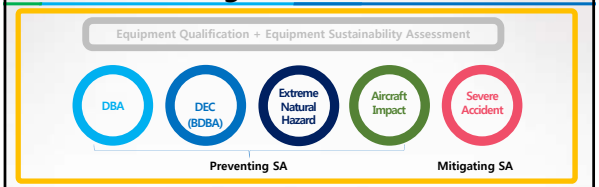

Risk Matrix	Severe Accident Policy Statement (Order, '01)	Accident Management Plan (Law, '16)
PSA Level 1 Core Damage Frequency(CDF)	<1.0E-4	<1.0E-4 (0.1 for New plants)
PSA Level 2 Large Early Release Frequency (LERF)	<1.0E-5	<1.0E-5 (0.1 for New plants)
Cs-137 100TBq Release	-	<1.0E-6

Overview of KHNP SOARCA Project

- Project Title
  - Optimization of Level 2&3 PSA Technologies based on SNL SOARCA Projects
- Pilot-Plants
  - Shin-Kori units 3&4 (SK 3&4, APR1400 series)
  - Wolsung unit 1 (WS-1, CANDU plant)
- Principal Investigating Organization : KHNP [Collaborated with KAERI, FNC & ACT and SNL (US)]
- Project Period : 2016.07 - 2019.06 (36 Months)
- Objectives
  - Regulatory requirement (resolution of safety issues raised from stress tests of NPPs)
    - ⑦-1 : Validity of coping capabilities and establishment of a response strategy in the Severe Accident situation caused by extreme natural disasters
    - ⑫-1 : Reduction of containment bypass possibility and preparation for coping measures
  - Updates on realistic accident progression and off-site consequence analysis based on latest severe accidents phenomena models and computational tools (e.g., MELCOR 2.2/ MAAP5, WinMACCS)
  - R&D of the state-of-the-art Level 2&3 PSA technologies for the diverse applications of plants under construction and operation (such as New Safety Goals, Multi-unit Risk and Accident Management Plan)

Overview of KHNP SOARCA Project

Objectives: *Development* of optimal evaluation technique of Severe Accident and off-site consequence based on the state-of-the-art technology and analysis tools

Step 1. Benchmarking and development of Latest technology

- Benchmarking of latest analysis technology (with SNL) and measures to resolve regulation issues
- Development of Level 2 PSA model (Accident progression, Severe accident mitigation and SAMG reflection etc.)
- Modeling of MELCOR/MAAP5/ISAAC Inputs for accident progression and radioactive source-term behaviors
- Development of Level 3 PSA (WinMACCS) input models (Site-specific, Food intake, evaluation of financial cost etc.)

Step 2. Optimum Analyses of Pilot-Plants

- Optimization of Level 2 PSA model and Severe accident code(MELCOR/MAAP5/ISAAC) input model
- Optimization of Level 3 PSA model (WinMACCS): Radiation reaction model and effect of resident reaction analysis etc.
- Optimization of off-site consequence analysis (Population Dose, Early/Cancer Fatality Risk, CCDF etc.)
- V&V of MELCOR/MAAP5/ISAAC) and WinMACCS input models (with SNL, FAI)

Step 3. Effective Management of SA Mitigation Systems and Regulation-responding Technology

- Development of Off-site risk analysis model(evaluation of mitigating system of severe accident, Solving with regulatory issue)
- Reliability evaluation of Severe Accident mitigation systems and suggestion of operation improvements
- Resolution of regulatory issues and requirement (PSA legislation and Wolsung#1 ST improvement plan fulfillment)

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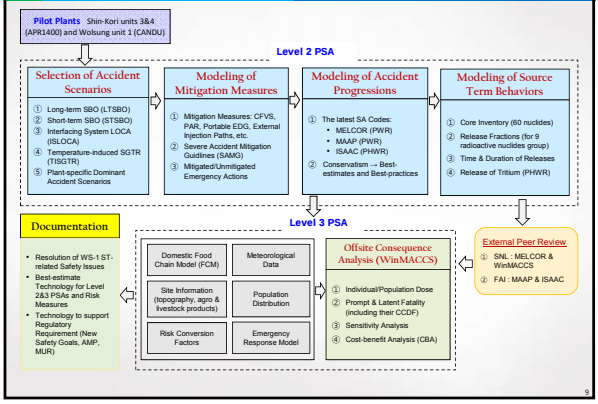
Project Direction & Strategy



Accident Scenarios Selection

❑ Scenario Screening Criteria

- Internal CDF Models : 1E-7/y for APR1400(using 1/10 of SOARCA)
  1E-6/y for CANDU(same as SOARCA)
- Selected scenario for APR1400
  - Full power internal event : LTSBO, STSBO, SGTR(w/o ISO, w/o SI), SLOCA, ISLOCA
  - Full power seismic event : STSBO, TI-SGTR, LOOP(w/o CSR, w/o F&B)
- Selected scenario for CANDU
  - Full power internal event : Loss of end shield cooling, Loss of IA, SLOCA, Feed line break, RCS Leak, Loss of Class 4 power, SGTR(w/o ISO, w/o SI), ISLOCA

❑ Scenario Comparison for PWR (APR 1400 vs Surry)

Scenarios	APR1400 (CDF>1.0E-7)	Surry (CDF>1.0E-6)	Remarks
Internal Event Scenarios	LTSBO	-	
	SGTR w/o ISO	Spontaneous SGTR	Bypass Sequence
	SGTR w/o SI		
	ISLOCA	ISLOCA	Bypass Sequence
	SLOCA	-	
External Event (Seismic) Scenarios	-	LTSBO	
	STSBO	STSBO	
	STSBO w/ TI-SGTR	STSBO w/ TI-SGTR	Bypass Sequence
	LOOP w/o CSR	-	
	LOOP w/o F&B	-	

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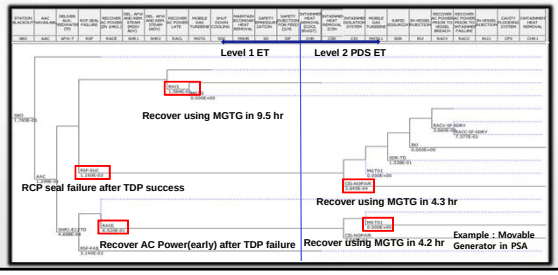
Mitigation Measures & Modeling

❑ **Reflection of Severe Accident coping measures in PSA model**

- Movable Generator(Supply emergency power), Movable Pump(External cooling to primary and secondary), CFVS/ECSBS(Containment depressurization), PAR (Hydrogen control in containment), POSRV(RCS depressurization) : EDMG & FLEX measures are considered in project
- HRA for SAMG and portable systems in PSA models

- APR1400(NEI 16-06/THERP) / CANDU(NEI 16-06/K-HRA)



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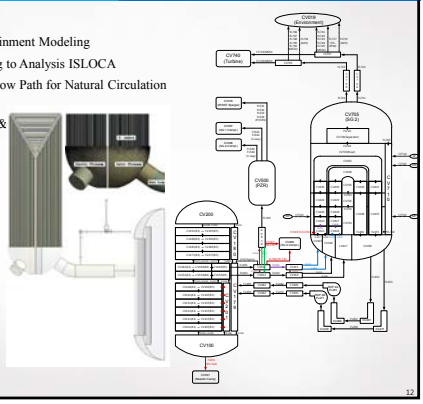
MELCOR 2.2 Plant Model

❑ **Outline of Modeling**

- RCS, SG, and Containment Modeling
- Aux. Bldg. Modeling to Analysis ISLOCA
- Detailed Nodes & Flow Path for Natural Circulation Simulation
- Hot leg, Surge Line & U-tube Creep Rupture Modeling
- POSRVs & MSSVs Fail Open Modeling (based on failure probability)
- CFD Analysis to Determine Natural Circulation Conditions (Large Steam Generator)
- Containment Design & Overpressure Leakage Modeling



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MELCOR 2.2 Plant Model

❑ **Difference in APR1400 Vs. Westinghouse 3-loop Plant (Surry)**

- Characteristic of Primary Relief Valve

Parameter	APR1400	Surry	Effect
Valve name	POSRV	PORV	
Opening area	Around twice the opening area of PORV in Surry		rapid decrease of RCS pressure when POSRV fails open → decrease of hot leg stress → decrease of hot leg failure probability by creep rupture
Blowdown	13% of opening area	4% of opening area	increase of the amount of mass & energy discharged By opening of one POSRV → decrease of the number of cycles → decrease of POSRV failure probability → maintain RCS pressure at POSRV opening pressure → increase of hot leg stress → increase of hot leg failure probability by creep rupture

- Pipe Section to cause ISLOCA
  - All pipe sections located outside containment have same schedules.
    → Any sections can be broken. → Broken sections can be located at any elevations.
    → The released fission products can be reduced by scrubbing effect or not.
  - All pipe sections are insulated → Different heat transfer trends → Influence to deposition
- Fission product release path
  - Complex release path of fission products by the ventilation systems of Aux. Bldg.
  - Major discharge point is outlet of HVAC chase located on the roof of Aux. Bldg.

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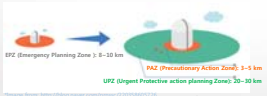
Level 3 PSA / Consequence Analysis

❑ **Development of WinMACCS Model & Input**

- Review materials
  - MACCS
    - Code manual & Model description
  - SOARCA
    - MACCS best practices as applied in SOARCA
  - Domestic
    - Technology status of off-site consequence analysis
    - Korean regulatory guidelines
- Comparison between US SOARCA & KHNP SOARCA
  - Domestic input & model
  - Site-specific data & emergency preparedness



  - Consideration of ingestion exposure pathway
- Key elements of KHNP SOARCA (in development)
  - Source term
    - Calculation of fuel inventory
    - Interfacing Level 2&3 PSA (plume release)
  - Site-specific data
    - Population & Land use data
    - Meteorological data
    - Topographic data (surface roughness)
    - Emergency response
    - Shielding & exposure factors
    - Food ingestion model
    - Economic data for cost estimation
  - Dose / health effect model
    - Dose conversion factors
    - Health effect model

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Expected outcomes & Plans

Focused Area	Improvement Points and Expectations
Mitigation Systems	▪ **Development of PSA models** taking into account Severe Accident mitigation systems (such as CFVS /ECSBS and PAR) and a newly-revised SAMG in Korea
Level 2 PSA	▪ **Evaluation of Severe Accident mitigation systems in aspect of** between mitigation and non-mitigation (approximately US SOARCA level) ▪ **Development of realistic and optimum analyses models for risk-dominant accident scenarios** (TI-SGTR, ISLOCA etc.) ▪ **Reducing Level 2 PSA-related uncertainties** (including accident progression states and inspection of containment integrity
Severe Accident & Relevant Tools	▪ **Analysis technique based on latest Severe Accident codes** (MELCOR, MAAP5, ISAAC) (optimal modeling/analysis of SA progression and source-term behaviors, etc.) ▪ **Applications of Severe Accident analysis results** through a code-to-code comparison between KHNP and Regulatory body ▪ **Review of technical issues and applicability through US SOARCA Benchmarking studies and V&V of Analysis results** (with SNL)
Level 3 PSA	▪ **Obtaining the capability of WinMACCS code analysis** (for a full-scope Level 3 PSA) ▪ **Obtaining the off-site consequence analysis capability reflecting domestic-specific conditions** (such as atmospheric spread, dose assessment, food intake, and emergency actions)

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Expected outcomes & Plans

Severe Accident / Level 2 PSA

- Severe Accident Progression Analysis(SK3,4 : MELCOR/MAAP / W1 : MAAP-ISAAC)
- MELCOR-MAAP Cross comparison(SK3,4)
- Optimal Time Evaluation and operational response of Severe Accident Management
- Provide Insights to AMP (meet New Safety Goal) / Derive Additional Improvements of Level 2 PSA

Level 3 PSA

- Source Term Analysis
- Level 3 PSA Input Development considering Site Characteristics
- Perform Off-site Consequence Analysis / Validate WinMACCS Model and Result
- Provide Insights to Multi-Unit Risk

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THANK YOU

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Accident Management Plan