

Studsvik

Studsvik CMS5 and S3R Update

January 2018

	M-	L-	K-	J-	H-	G-	F-			
				0.73 3.56	0.88 4.41	0.72 3.53				
		0.77 3.46	1.01 4.79	1.11 5.35	0.98 22.35	1.10 5.30	1.01 4.76			
			0.81 3.61	1.09 4.78	1.18 5.28	1.10 20.26	0.94 25.40	1.10 20.23	1.18 5.27	
			0.81 3.61	0.97 21.81	1.22 5.46	1.16 21.53	1.17 12.50	1.01 26.18	1.17 12.48	1.16 21.52
05	0.77 3.45	1.09 4.78	1.22 5.46	1.08 26.46	1.20 13.18	1.20 11.70	1.16 19.38	1.20 11.70	1.20 13.13	
06	1.01 4.77	1.18 5.27	1.16 21.48	1.20 13.14	1.12 24.96	1.27 5.84	1.10 26.59	1.27 5.83	1.12 24.96	
07	0.72 3.53	1.10 5.30	1.10 20.23	1.18 12.48	1.20 11.67	1.27 5.83	1.12 24.90	1.24 5.61	1.12 24.89	1.27 5.84
08	0.88 4.42	0.98 22.35	0.94 25.38	1.01 26.16	1.16 19.08	1.10 26.58	1.24 5.61	0.90 20.71	1.24 5.61	1.10 26.58
09	0.73 3.57	1.11 5.36	1.10 20.26	1.17 12.50	1.20 11.67	1.27 5.84	1.12 24.89	1.24 5.61	1.12 24.90	1.27 5.83
10		1.01 4.79	1.18 5.28	1.16 21.49	1.20 13.17	1.12 24.96	1.27 5.83	1.10 26.59	1.27 5.84	1.12 24.96
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Status

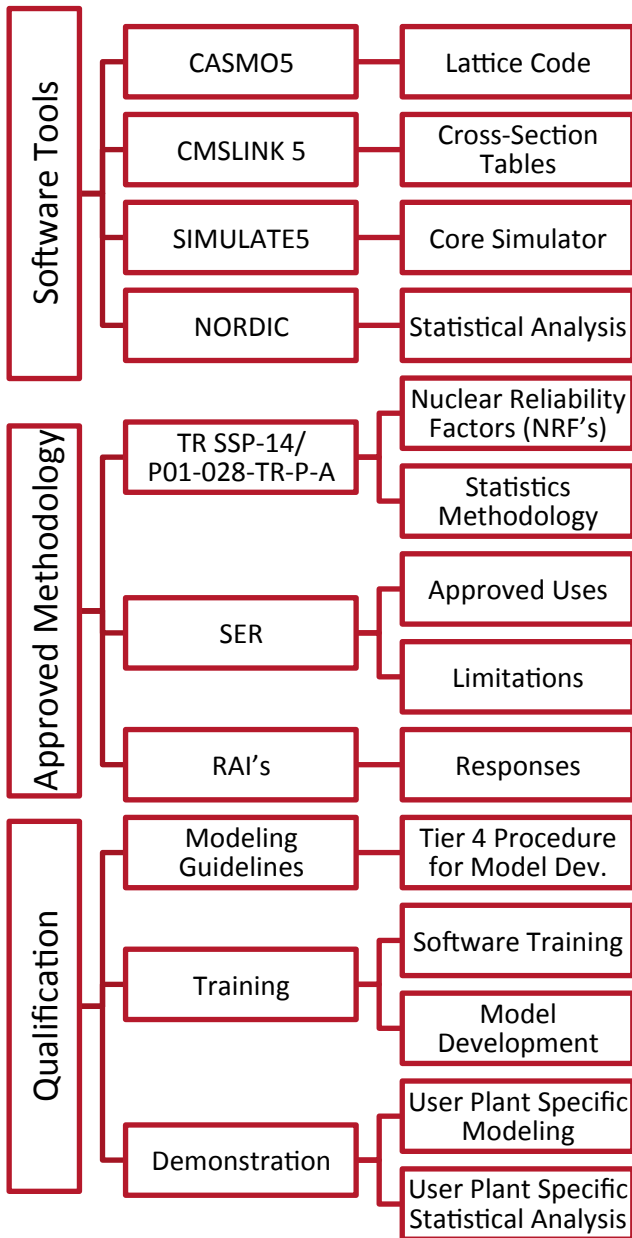
- 78 S3Rs worldwide (3 new, 2 updates in progress)
- Topical Report Product for Generic License Core Design using CMS
- VVER methods development

Outline

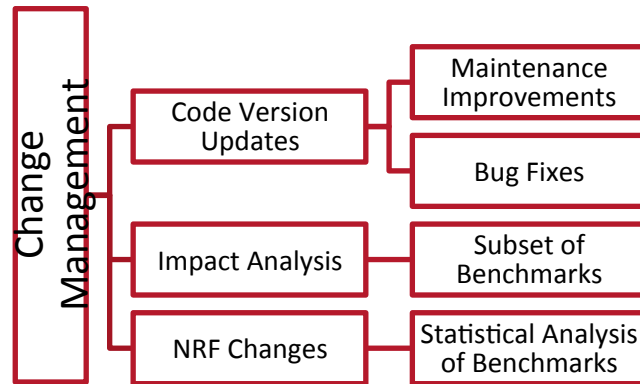
- Independent Method Development and Adoption
- USNRC Generic Licensing Process
- SSP Approach
- Topical Report Structure and Product
- Components of TR Application

Generic PWR license for CMS5

- To create added value for SSP customers with CMS5 and to reduce repetition with the NRC during reviews, Studsvik Scandpower decided to submit a CMS5 PWR Generic Topical Report, per LIC-500 guidance.
- The customer gains the following risk/cost reductions and assistance from Studsvik Scandpower.
 - No review fees with the USNRC, this can be a significant cost, and risk in today's tough energy market. This is saving of hundreds of thousands of dollars.
 - Reduced schedule risk. With the acceptance review approaching completion and timeline for the SER will be forthcoming. This adds the ability for a customer to reference a TR already in review.
 - Internal Customer Man Hour cost reductions. The customer can now focus on modeling work that is important to their units and projects, not repeating benchmarks.
 - Experience of the SSP staff and partners who prepared the TR. A comprehensive set of modeling guidelines have been produced to allow customers to produce consistent models from the very beginning.
 - Version control in-house or with SSP assistance. Options for the TR can allow customers to move to updated code version using in-house change management, or SSP can provide the updated code versions using SSP change management procedures.
 - Ease of adoption by using the USNRC Generic Letter 83-11 process no approval by the USNRC is needed.



CMS5 and Generic PWR TR



Scope That Applies to Simulator

- The information presented in the TR demonstrates that the CMS5 codes are acceptable for performing all core physics analyses as the licensing code of record separately from the fuel vendor including:
 - Reload Design
 - Safety Analysis Input
 - Startup Predictions
 - Plant Physics / Operator Data Books
 - Reactor Protection and Monitoring System Updates
- No “two clock” problem with computed reference data
- Same level of compatibility with S3R
(6 CMS5-based S3Rs installed or in progress)

Range of Applicability

Parameter	Range
Pin Lattice Geometries	Square Pitch Lattice
Integral Burnable Absorber	[Gd ₂ O ₃ , IFBA [®] ZrB ₂]
Fixed Burnable Absorber	[WABA [®] B ₄ C-Al ₂ O ₃ Boron Silicate Glass Hafnium Suppression Rods]
Control Rod Absorber	[AlC B4C Tungsten, Hafnium]
U235 enrichments	[Natural – 5.0 w/o]
In-Core Detector Types	[Movable Fission Chambers Fixed Rhodium]
Soluble Boron	[0-2500 ppm]

CMS5 PWR Generic TR Product

- As a product the TR is more than just a report. Customers have many optional components to select from to suit their needs
- Base Components
 - Access to the proprietary version of the TR within a negotiated scope of use.
 - Ability to use the Generic NRF's generated in the report. Optional Components
 - Access to the modeling guideline procedure developed by SSP. Using worked examples of all typical calculations performed for benchmarking.
 - Advanced training using the modeling guidelines and generic model. Results will only be shared at the end as a way to demonstrate engineer proficiency. This can be tailored to fit within an INPO compliant training program.
 - Tools that implement the approved NRF methodology to automate the process for customer operational units. Change Management Support From SSP to move the TR approved codes to updated versions.
 - For Non-USA implementation SSP assistance in preparing appropriate regulatory documents needed in the country of implementation.

Nuclear Reliability Factor (NRF) Methodology

- Process (with Bases) to determine appropriate factors to apply to CMS5 predictions
 - Intended to be used by licensees who have “bounding parameter” style core reload design processes
 - Two main methods of determining conservative NRFs for each reload parameter
- [Statistically determined (One-sided tolerance limit)
 - Suitable for parameters for which differences between predictions and measurements can be made
 - Statistical methods including distribution testing and tolerance limit construction are described
 - Examples: integral control rod worth, total reactivity difference, peaking factors (FQ, FΔH)]
- [Non-statistically determined
 - Suitable for parameters for which differences between predictions and measurements can not be made OR for parameters that have a high degree of measurement uncertainty
 - Engineering arguments, related physics parameter analysis, plant transients and industry standards are used to arrive at conservative estimate of NRF
 - Examples: Doppler feedback coefficient, differential boron worth, delayed neutron and prompt neutron lifetime data]

NRF Methodology Application

- The proposed NRF methodology will be applied to 7 PWR reactors.
- The benchmark will include over 60 cycles of data.
- Measurement Comparisons are made to:
 - Critical Boron Concentration
 - Startup Physics Test Predictions
 - Flux Maps
- Plant A, Westinghouse 2-Loop System
 - 14x14 Small Water Hole Lattice
 - Offset Movable Fission Chamber Incore Detectors
- Plant B, CE 2x4-Loop System
 - 14x14 Large Water Hole Lattice
 - Fixed Rhodium Incore Detectors.
- Plant C, Westinghouse 4-Loop System
 - 17x17 Small Water Hole Lattice
 - Movable Fission Chamber Incore Detectors
- Plant D, 2 Units, Westinghouse 3-Loop System
 - 15x15 Small Water Hole Lattice
 - Movable Fission Chamber Incore Detectors
- Plant E, 2 Units, Westinghouse 3-Loop System
 - 17x17 Small Water Hole Lattice
 - Movable Fission Chamber Incore Detectors

Plant Benchmark Derived Generic NRF Results

- The NRFs are derived at 95/95 one sided tolerance limits.
- Where units in the tolerance limit columns are provided in the table an additive NRF is used on the calculated quantity.
- Where no units in the tolerance limit columns are provided the NRF is a multiplier on the calculated value.
- Note: Values that cannot be measured are supported by engineering judgement and historic precedence. Such as Prompt Neutron Lifetime, Delayed Neutron Fraction, Doppler, Differential Boron Worth

Parameter	NRF	
	Upper	Lower
Total Reactivity	XXX pcm	XXX pcm
Integral Rod Bank Worth (Individual banks) (pcm)	XXX	XXX
Peak Differential Control Rod Worth (pcm)	XXX	XXX
ITC/MTC	XXX pcm/°F	XXX pcm/°F
Differential Boron Worth (pcm/ppm)	XXX	XXX
Doppler Temperature/ Power Coefficient (pcm/°F)	XXX	XXX
Peaking Factor FAH/Fr (movable and fixed incore)	XXX	N/A
Peaking Factor FQ (movable and fixed incore)	XXX	XXX
Kinetics Parameters (Delayed Neutron Fraction, Prompt Neutron Lifetime)	XXX	XXX

Sample of Uncertainty in Licensed Methods

Typical Xe-135 Worth

Burnup (GWdT)	Vendor (pcm)	CMS5 (pcm)	S3R (pcm)
0.00	2545	2560	2556
0.15	2562	2563	2558
3.00	2564	2595	2587
10.50	2690	2733	2726
14.90	2783	2819	2815
17.70	2840	2873	2870

Impact for Customer

- Streamlined Licensing Path
- Vendor Independence
- Complete consistency in Physics Methods
- Data Book, SOR developed in the one system

CMS and S3R for VVER

- CASMO5/SIMULATE5 extended to VVER
- Same features as “square” CMS
- Lead Customer FennoVoima (VVER 1200)
Code system developed in tandem with the plant
- Methods available July 2018
(sooner for FennoVoima)

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