

Peak Cladding Temperature Prediction Using Deep Learning

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Presentation Outline

Partl: Introduction

SBO simulation

• Part II:

Uncertainty analysis.

• Part III: Methodology and Results

- ► Al concept.
- Database and model Development.
- ➢ Model architecture.
- ➢ Results.







Part I: SBO condition – Simulation – MARS-KS



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Junghyun Yun, Taewan Kim, Jonghyun Kim, 'Verification of SAMG entry condition for APR1400'', Annals of Nuclear Energy, Volume 75, 2015.

Figure2-APR 1400 nodalization





Part I: SBO condition – Simulation

- Base case model developed and compared with DCD documents.
- A transient file was written by reflecting the components required to simulate SBO accident.
- As shown in Figures 2 and 3, FLEX pumps had been applied on primary and secondary sides.
- Seal leakage effect were studied parametrically and modeled as shown in Figure 2.



Figure 3 – FLEX implementation on primary side





Eight assumptions were considered to develop SBO simulation code:

- > FLEX pumps are aligned at two hours after accident initiation.
- ➤ The seal leakage rate of RCPs is 21 gpm [1] and [2].
- > The battery power and TDAFWP are depleted after 8 hours operation.
- > Feed and bleed operation is applied on the secondary side.
- Safety injection pump is unavailable.
- Shutdown cooling pump is unavailable.
- Auxiliary charging pump is unavailable.
- Motor driven auxiliary feed water pump is unavailable.

Kang et al. [1] Westinghouse RCP seal leakage report [2]







Part II: Uncertainty Analysis

Table I – Uncertain parameters corresponding to different physical phenomena [1], [3], and [4]

Phenomenon	Uncertain parameter (symbol)					
Thermal power generation in core	Initial total reactor power (P1)					
Thermal power generation in core	Decay heat power (P2)					
Primary system energy accumulation	Fuel heat capacity (P3)					
I milary system energy accumulation	Fuel conductivity (P4)					
	Initial pressure in pressurizer (P5)					
Primary and secondary systems pressure	Set point for pressurizer relief valve (P6)					
control	Initial pressure in the steam generator (P7)					
	Multipler for liquid Dittus-Boelter correlation (P8)					
Heat removal (from primary and secondary systems)	Multipler for vapor Dittus-Boelter correlation (P9)					
	Multiplier for Chen nucleate boiling model (P10)					
	Initial total mass flow rate (P11)					
Coolant flow (primary system)	Total moment of inertia for circulation pumps (12)					
	Initial coolant inventory in SITs (P13)					
Coolant injection by amargancy Core	Initial pressure in SITs (P14)					
Cooling Systems ECCSs and mobile pumps	Initial coolant temperature in SITs (P15)					
(primary and secondary systems)	Initial temperature in the mobile pumps (P16)					

Table II – Uncertain parameters Characteristics

Symbol	Range	Distribution
P1	0.98-1.02	Normal
P2	0.92-1.08	Uniform
P3	0.98-1.02	Normal
P4	0.90-1.10	Normal
P5	0.974-1.026	Uniform
P6	0.982-1.017	Uniform
P7	0.974-1.026	Uniform
P8	0.85-1.15	Uniform
P9	0.8-1.2	Uniform
P10	0.8-1.2	Uniform
P11	0.95-1.05	Uniform
P12	0.8-1.2	Uniform
P13	0.88-1.12	Normal
P14	0.93-1.23	Uniform
P15	0.93-1.23	Uniform
P16	0.94-1.06	Uniform

The identification of uncertain parameters for this work is based on the PIRT developed by Kang et al. [1] and the uncertainty analysis performed by Kozmokov et al. [3] and by Lee et al. [4].







Part II: Uncertainty Quantification









Part II: AI Implementation – Sampling of data









Part III: Methodology and results







Part III: Layered approach



Figure 9 – Neural network mechanism







Part III: Prediction framework



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Part III: Inputs selection

Pl	P2	P3	P4	P5	P6	P7	PB	P9	Pio	Pil	P12	Pis	P14	P15	PIG	P17
0.54	0.028	-0.045	0.019	-0.01	0.021	0.05	-0.29	0.089	-0.092	-0.72	-0.0029	0.011	-0.0033	0.0073	-0.019	1
0062	-0.0093	0.0012	-0.0067	-0.0025	0.0057	0.0093	-0.0037	0.0035	-0.0079	0.01	0.00096	-0.013	0.012	0.0092	1	-0.019
0.0038	-0.0047	-0.0012	-0.0095	0.017	0.0035	0.022	-0.0051	-0.011	0.0046	-0.0093	0.0053	-0.0028	-0.0043	1	0.0092	0.0073
0064	-0.0098	0.00058	-0.028	0.0098	0.0058	-0.0031	0.017	-0.0029	0.0026	0.0039	0.0056	-0.015	1	-0.0043	0.012	-0.0033
0025	-0.0094	-0.0055	0.012	-0.0024	-0.0061	-0.0059	0.0038	-0.0008	0.015	-0.0054	-0.0093	1	-0.015	-0.0028	-0.013	0.011
0.025	0.0088	-0.0093	0.022	0.0094	-0.0098	0.016	-0.0048	-0.0066	0.0096	0.0047	1	-0.0093	0.0056	0.0053	0.00096	-0.0029
0.014	-0.013	-0.033	-0.0074	0.0062	0.00079	0.012	0.0026	0.016	-0.02	1	0.0047	-0.0054	0.0039	-0.0093	0.01	-0.72
0.0013	0.0096	0.0055	-0.0044	0.00066	0.011	-0.004	0.0012	-0.02	1	-0.02	0.0096	0.015	0.0026	0.0046	-0.0079	-0.092
0.005	0.018	0.0091	0.011	-0.0093	0.023	0.0037	-0.0046	1	-0.02	0.016	-0.0066	8000.0-	-0.0029	-0.011	0.0035	0.089
0.011	-0.007	0.0041	0.0016	-0.00029	0.0058	0.031	1	-0.0046	0.0012	0.0026	-0.0048	0.0038	0.017	-0.0051	-0.0037	-0.29
0.0079	-0.02	0.016	0.0078	-0.0085	-0.02	1	0.031	0.0037	-0.004	0.012	0.016	-0.0059	-0.0031	0.022	0.0093	0.05
0.011	-0.0084	0.0037	0.0022	0.005	1	-0.02	0.0058	0.023	0.011	0.00079	-0.0098	-0.0061	0.0058	0.0035	0.0057	0.021
.0014	-0.0033	0.017	0.014	1	0.005	-0.0085	-0.00029	-0.0093	-0.00066	0.0062	0.0094	-0.0024	0.0098	0.017	-0.0025	-0.01
.00063	-0.0097	-0.016	1	0.014	0.0022	0.0078	0.0016	0.011	-0.0044	-0.0074	0.022	0.012	-0.028	-0.0095	-0.0067	0.019
0.024	0.0087	- 1	-0.016	0.017	0.0037	0.016	0.0041	0.0091	0.0055	-0.033	-0.0093	-0.0055	0.00058	-0.0012	0.0012	-0.045
0.021	1	0.0087	-0.0097	-0.0033	-0.0084	-0.02	-0.007	0.018	0.0096	-0.013	0.0088	-0.0094	-0.0098	-0.0047	-0.0093	0.028
1	0.021	-0.024	-0.00063	0.0014	0.011	-0.0079	0.011	-0.005	-0.0013	-0.014	-0.025	0.0025	0.0064	-0.0038	-0.0062	0.54

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Figure 13 – Correlation matrix





- -0.2

-0.4

- -0.6

Part III: Model's architecture



Figure 14 – ANN model architecture







Part III: Optimization and model architecture



Figure 15 – ANN model configuration to predict the PCT.

Number	Hyperparameter	Туре	Value (in this work)			
1	Optimizer	categorical	Adam			
2	Initializer	categorical	Normal			
3	Learning rate	Numerical	3.0007			
4	Activation function (output layer)	Categorical	Linear			
5	Network shape (configuration)	Categorical	Triangle			
6	Epochs	Numerical	1000			
7	Number of neurons if the first hidden layer	Numerical	32			
8	Batch size	Numerical	41			
9	Hidden layers number	Numerical	1			
10	Dropout	Numerical	0			
11	Activation function (input layer and hidden layers)	Categorical	Relu			

Table III - Best model's hyperparameters found by Talos







Part III: Results









Thank you





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