Use of Best Estimate Methods in licensing of VVER reactors

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Introduction

- The conservative and best estimate approaches have been used in most countries, even though regulatory bodies in different countries have tailored these approaches to fit their particular needs.

- Present regulations permit the use of best estimate codes, but there may be added requirements for conservative input assumptions, sensitivity studies or uncertainty studies.

I shell now try to present:

- **Brief description and selection of methodology for uncertainty and sensitivity analyses.**
- **Description of uncertainty methods and philosophy of their selection.**
- **Examples of use**

Using uncertainty analysis of the input data and computer models .

Under preparation is a proposal of the methodical procedure to be applied for thermo hydraulic analyses of some initiating events for VVER-440/213 and VVER-1000/320 reactors, which takes into account general trends and especially – IAEA and OECD recommendations.

Considered is, for instance, application of this method for the evaluation of such events as

"leak on the secondary side-MSLB",

SB LOCA,

LB LOCA,

PRISE and

Loss of Flow

Conservative versus best estimate approach

Applied codes	Applied codes Input & BIC (boundary and initial conditions)	Assumptions on systems availability	Approach
Conservativ codes	Conservative input	Conservative assumptions	Deterministic
Best estimate (realistic) codes	Conservative input	Conservative assumptions	Deterministic
Best estimate codes + Uncertainty	Realistic input + Uncertainty	Conservative assumptions	Deterministic
Best estimate codes + Uncertainty	Realistic input + Uncertainty	PSA-based assumptions	Deterministic + Probabilistic

A conservative approach

does not give any indication:

- **about actual plant behaviour,**
- **including timescale,**
- **for preparation of EOPs or**
- **for use in accident management and**
- **preparation of operation manuals**
- **for abnormal operating conditions.**

Selection of an uncertainty method for solution of a particular task

Was based on comparison of all monitored methods

We come to the conclusion that the most suitable will be the nonparametric method based on Wilk's Formula

(GRS, IRSN).

This method has the following characteristics and advantages:

- **General**
- **Technical, specific.**

General:

- The method and SW are available for use at the (UJV-NRI)
- The method is applied in Germany and France
- The AEAT and ENUSA methods have similar theoretical base
- Extensive experimental databases of high accuracy are not needed (in comparison with the UNI PISA method)
- The method is published and presented in sufficient details
- Close co-operation exists between the UJV and author organizations
- The method is independent on the computer code
- Full statistic software operates on PCs under MS Windows operating system

Technical specifics:

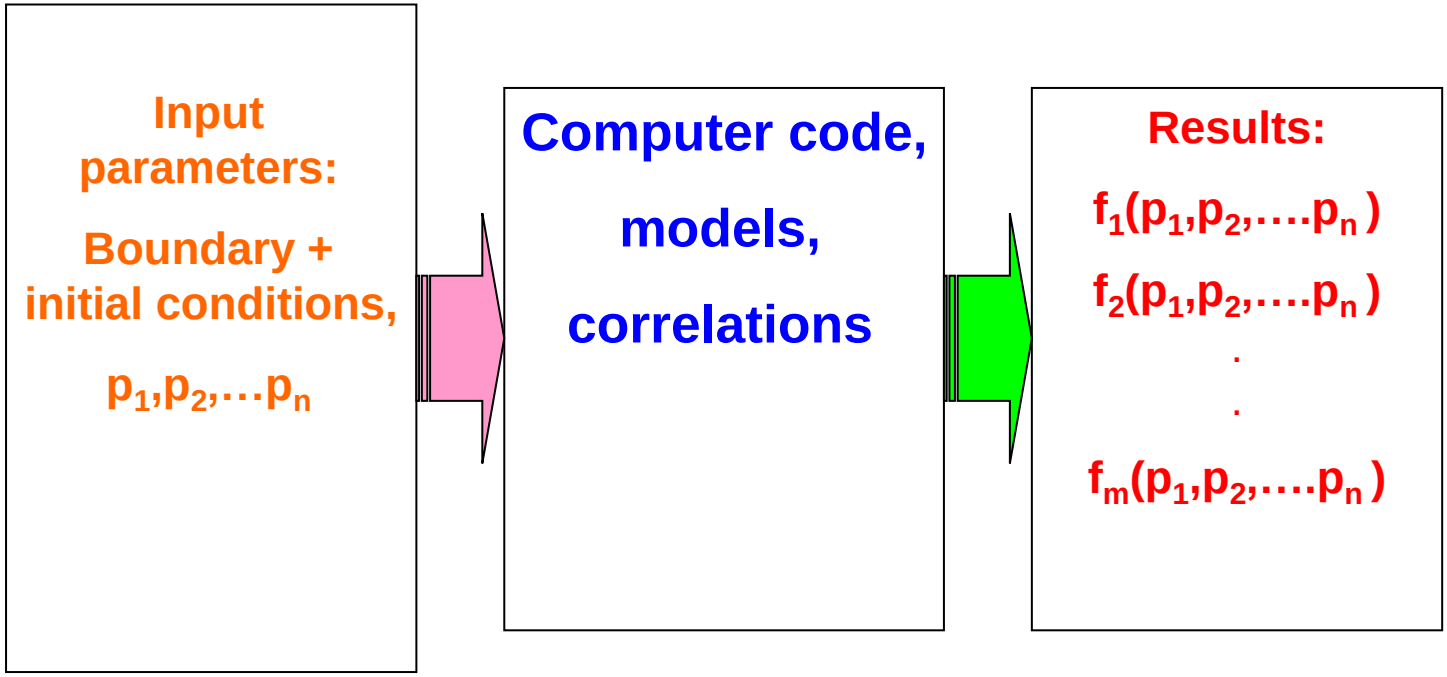
All suitable and available experimental data can be applied

The specified ranges and uncertainty distributions of input data apply for whole transient process

Number of repeated TH calculations depends on the reliability statistic limits (Wilk's equation). It does not depend on number of input parameters

The method can be applied both for uncertainty and sensitivity analyses

BE Aproach


Input parameters:
Boundary + initial conditions,
$p_1,p_2,\ldots p_n$
Computer code, models, correlations
Results:
$f_1(p_1,p_2,\ldots.p_n)$
$f_2(p_1,p_2,\ldots.p_n)$
.
.
$f_m(p_1,p_2,\ldots.p_n)$

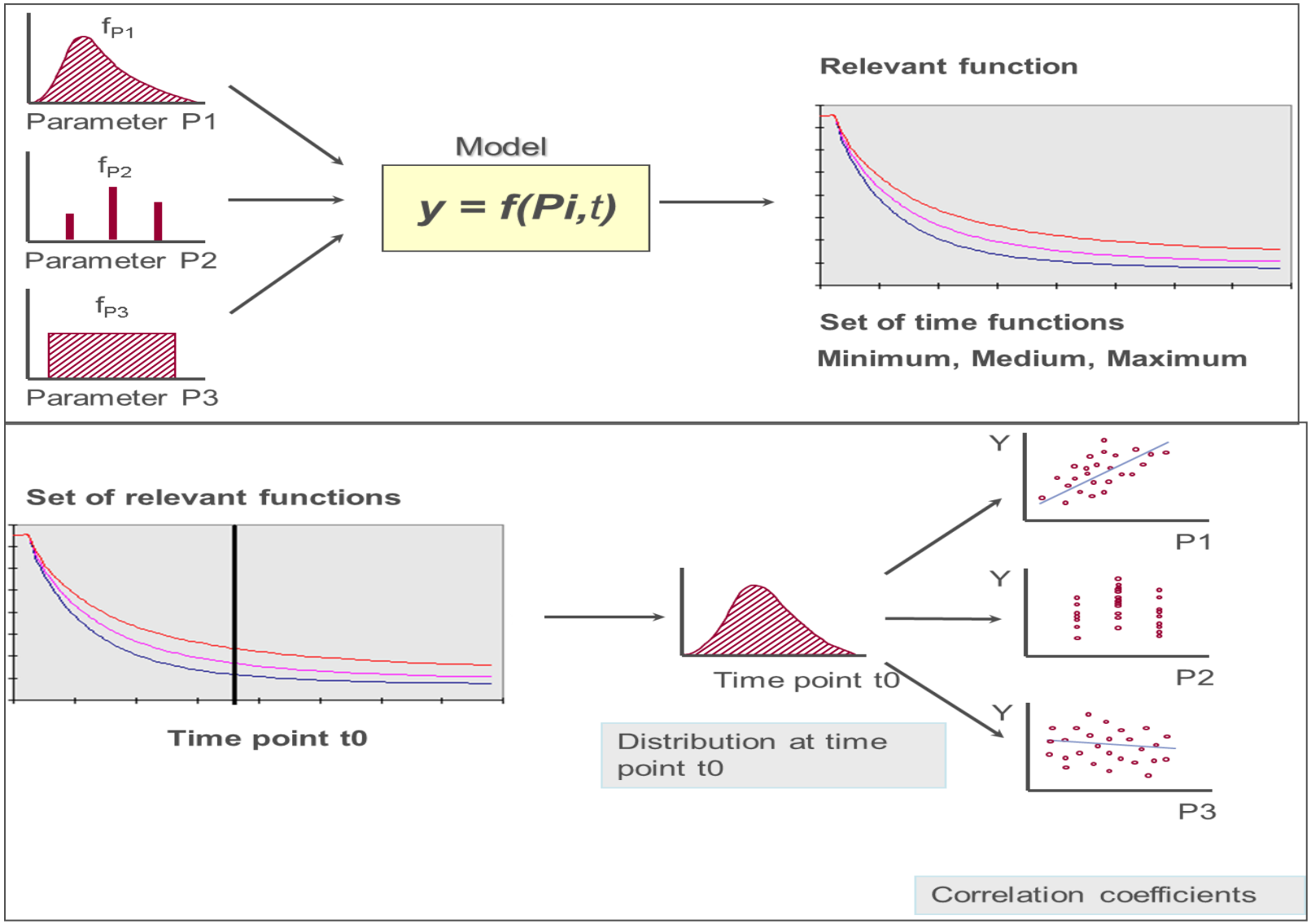
The number of calculations to cover a combination of different input parameters

- We have p input parameters
- Select the maximum, minimum and the reference value for each parameter (3 parameter values)
- The number of calculations required is n
- When you combine parameters is:

$$n = 3^p$$

p	n
5	2.43E+02
10	5.90E+04
20	3.49E+09
30	2.06E+14
40	1.22E+19
50	7.18E+23
60	4.24E+28
70	2.50E+33
80	1.48E+38
90	8.73E+42
100	5.15E+47

BE Aproach
(GRS-Glaeser)



One side tolerance limit, Wilks equation

Wilksova formula gives the relationship between the required number of analyses carried out n, and uncertainty and the reliability of the results obtained (β, ϰ).

m - is a order of Wilks formula

$$m = 1 \qquad Y_{(1)} \qquad Y_{(n)} \qquad (\gamma, \beta = 0.95)$$

$$\gamma = 1 - \beta^n$$

$$n > n_0$$

$$m = 2 \quad \gamma = 1 - n\beta^{n-1} + (n-1)\beta^n$$

$$m > 2 \quad \gamma = 1 - \sum_{i=0}^{n-m} \binom{n}{i} \beta^i (1-\beta)^{n-i}$$

One side, Wilks equation

The minimum number of calculations n for uncertainty and the reliability of the results

(β, ϰ) = 95%. .

n	m	β=γ	Lower limit	Upper limit
59	1	0.95	$Y_{(1)}$	$Y_{(59)}$
93	2	0.95	$Y_{(2)}$	$Y_{(92)}$
124	3	0.95	$Y_{(3)}$	$Y_{(122)}$
153	4	0.95	$Y_{(4)}$	$Y_{(150)}$
991	39	0.95	$Y_{(38)}$	$Y_{(953)}$

Examples of BE-GRS methodology

Important points of BE method:

- **Validation of computer code on experiments**
- **Definition of uncertainties input parameters**
- **BE analysis on the integral test facility, uncertainty and sensitivity**
- **Definition of uncertainties input parameters of real NPP, scaling effect**
- **Analysis of NPP**

Examples of BE-GRS methodology

IU	Scenario according to Chap. 15 of SAR NPP Temelín	Criterion					Remarks
		AC1 Primary pressure	AC1 Secondary pressure	AC2 DNBR	AC3 Fuel temperature	AC4 Cladding temperature	
15.1	Increase in heat removal by the secondary system						
15.1.5	Spectrum of steam system piping failures inside or outside the containment						
15.2	Decrease in heat removal by the secondary system						
	Turbine trip (closing of TG stop valves)						
	Loss of normal feedwater flow						
15.3	Decrease in reactor coolant system flow rate						
	Sequential loss of forced reactor coolant flow						
	Complete loss of forced reactor coolant flow (all MCP trips)						
	MCP shaft seizure (locked rotor)						
15.4	Reactivity and power distribution anomalies (RIA)						
	Uncontrolled RCCA bank withdrawal at power						
	Spectrum of RCCA ejection accidents						
15.5	Increase in reactor coolant inventory						
15.6	Decrease in reactor coolant inventory						
	Inadvertent opening of a pressurizer safety or relief valve						
	SG internal manifold failure						
	Loss-of-coolant accident (LOCAs) (small break)						
	Loss-of-coolant accident (LOCAs) (large break)				Not limiting		The basic criterion is AC4.

Examples of BE-GRS methodology
The use of BE-access the Best Estimate

The methodology of the Best Estimate for SA processed events:

- **LB LOCA**
- **SB LOCA**
- **PRISE**
- **Seizure of the rotor of MCP**
- **Loos of flow**
- **MSLB**

Thank you for your attention