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Research Article

Regulatory Scenario for the Acceptance Uncertainty Analysis Methodologies for and the Brazilian Approach

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Abstract

The task of regulatory body staff reviewing and assessing a reali model is discussed, facing the actual regulatory licensing enviror emergency core cooling system performance. Especially, focus requirement of quantifying the uncertainty in the calculated res criteria for this system. As it is recognized that the regulation gc originally developed by the United States Nuclear Regulatory Com When using a realistic evaluation model to analyze the loss-of-coo in the licensing arena. The Brazilian regulatory body has concludec regulatory calculation is recognized as a relevant support for the realistic analysis.

1. Introduction

The objective of this paper is to discuss the regulatory licensing en of emergency core cooling system (ECCS) performance in light wa evaluation model. The focus is directed to the question of how to r in the calculated results when they are compared to the acceptanc

It also included the experience of the Brazilian nuclear regulatory nuclear power plant (NPP) large-break loss-of-coolant accident (realistic evaluation methodology.

2. Regulating the Use of Be + U

The United States Nuclear Regulatory Commission (USNRC) em issued in 1974 [1], is recognized as a highly conservative approac relevant aspect was identified and dealt with by the nuclear com research area. For additional details, see [2 - 6].

In 1983, based on experimental programs results, the ability of during a LOCA was demonstrated, and the conservatism in Appen this, through the release of SECY-83-472 [7], the NRC adopted a the features of Appendix K which were recognized as requirement that, models and correlations are stated as acceptable. Even still licensing decision making based on realistic calculations.

On September 16, 1988, the NRC amended the requirements o understanding of the thermal-hydraulic phenomena occurring du results of extensive research programs sponsored by the NRC and revision which allows, as an option, the use of realistic evalua emergency core cooling system. In such cases, the LOCA anal evaluating the uncertainty in the analysis methods and inputs, comparing the calculated results with the acceptance criteria so t not be exceeded.

This revision of 10 CFR 50.46 allows licensees or applicants to use Appendix K, with its conservative analysis methods, or a realistic analysis methods). The Regulatory Guide 1.157 [9] describes acce procedures, and methods for meeting the specific requirements fo a LOCA.

Despite of that, there is still a lack of an established set of specifi the acceptance of the uncertainty calculation related to the results LOCA. On January 11, 2001, the Advisory Committee on Reactor S of how the perceived weaknesses of the thermal-hydraulic co emphasized in a Letter Report [10], “We perceive a need for the methods of deriving and expressing the uncertainties in codes regulatory context” .

More recently, NRC has issued section 15.0.2 of the Standard Re acceptance criteria for analytical models and computer codes use including methods to estimate the uncertainty in best-estimate industry was issued, set forth in Regulatory Guide 1.203 [12]. De its January 11, 2001 Letter Report related to Regulatory Guide remain very qualitative and leaves considerable latitude in interpre

In parallel, NRC has been conducted research, together with indus an example, it should be mentioned that the ongoing devel

embrittlement criteria in 50.46(b) [13 - 15], and also the propose
related to the definition of LOCA break sizes [16].

In the United States, the first NRC approved best-estimate LOCA
[17], patterned after the Code Scaling, Applicability, and Uncer
response surfaces to estimate PCT uncertainty distribution with t
Carlo sampling and accepted as the licensing basis PCT. In 1999,
2-loops plants with upper plenum injection). By 2000, 14 plants
methodology as a licensing basis and it was also used for Ringhals

Framatome ANP has submitted its realistic LB-LOCA methodology a
approach but was the first to use a nonparametric order statistic r
By 2006, there were seven completed realistic LB-LOCA anal
Combustion Engineering pressurized water reactors [20].

By 2004, Westinghouse updated its methodology to use nonpara
treatment of uncertainty method (ASTRUM) [21] was approved fo
or analyzed with Westinghouse 1996 and 1999 BELOCA methodolo
with ASTRUM [18].

It is worthwhile to mention the ongoing issue at the regulatory ar
methodology to demonstrate that the criteria in 10 CFR 50.46(b
evaluation model runs accepted to demonstrate a probability that
similar realistic LB-LOCA methodologies approved by the NRC [19
to demonstrate the simultaneous satisfaction of the first thr
temperature, peak local oxidation, and corewide oxidation. There a
issue [22 - 26].

In Germany, the use of best-estimate codes is allowed, in cor
conditions, and efforts are being conducted to include uncertainty
German nuclear regulation. There is also a recommendation of
licensing analysis [27].

In Canada, the Canadian Nuclear Safety Commission recently con
for safety assessment and applications of best-estimate analysis ar

3. Brazilian Regulatory Experience

Angra 2 NPP is a 4-loop Siemens design 1300 MWe pressurized w
2001. The best-estimate LOCA approach was formally adopted by
when the realistic LB-LOCA analysis was submitted, based on CSA
were only few applications of realistic evaluation models in the lice

Aiming at performing a consistent safety review and assessment o
its staff and relied upon two international consultants, the Ger
Reaktorsicherheit) and the University of Pisa.

The cooperation with many international institutions involved i
technical background for the regulatory staff. In the same time, t
coordinated by CNEN, has promoted the integration of seven inst
utility) of the Brazilian nuclear sector. One result of JONATER was
an exercise for Angra 1 NPP, a Westinghouse 630 MWe 2-loop pre

estimated with the UMAE [29] method for the results of the small
as it is shown in Figure 1 [30].

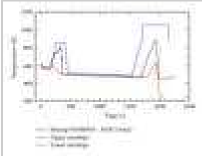

Figure 1: JONATER application of UMAE to a
PCT.

UMAE is an uncertainty methodology based on accuracy extrapo
results and relevant experimental data obtained in experimental
chosen transient scenario, with an established nodalization that w
plant calculation. The extrapolated accuracy is superimposed
Uncertainty bands are constituted by a set of “punctual” error ba
Y_C quantity). Each value Y_C at a time t can be characterized by an e
the “x” direction. The total uncertainty is the superimposition of

As the estimation of Angra 1 small-break LOCA uncertainty b
uncertainty methodology, for the accuracy calculation, only th
considered (experimental and Relap5/Mod2 results for the SB-
accuracy should be obtained from more tests to avoid some poor a
parameter. For instance, code simulation of the LSTF experiment
time of its occurrence far from the verified experimental value. T
the transient for the peak cladding temperature shows no physica
data used.

The Angra 2 LB-LOCA analysis presented in the final safety-analy
account the two independent reviews performed by the internati
evaluation report (SER) requested additional information (RAI), wi
is classified according to their significance to safety [31].

Table 1 lists the main steps in the review and assessment process

Table 1: Angra 2 NPP LB-LOCA Review.

The Siemens uncertainty methodology applied to Angra 2 follow
Identification Ranking Table, code capabilities for accident scenari
surface. The treatment of the uncertainties is performed separate
(statistical quantification of difference between calculated and
(statistical variations), and fuel parameters uncertainties (statistic
to uncertainties have been required to be run at combined worst
and location, axial core power distribution, worst-case single failur
reactor kinetics.

This uncertainty analysis is such that the 95% probability PCT
uncertainties from the three sources. The two other criteria (maxi
were calculated considering conservative assumptions.

The number of data points, used to determine code accuracy thr
calculated and measured results for LOFT and CCTF experiments,

It was further required from the applicant to verify the implicatic data into code integral uncertainties. Additionally, the applicant p experimental data.

After the issuance of the preliminary SER, the importance of an i Together with CNEN staff, the University of Pisa performed indeper three requests for additional information were issued to the applic be consistent with those used for the validation calculations.

As future applications, the Brazilian regulatory body has already l uprate 6% the Angra 2 power together with a change in the fuel fuel with M5 fuel cladding. This will require the reanalysis of the LB

Furthermore, for Angra 1 NPP steam-generators replacement, the the LB-LOCA, using the Westinghouse methodology that encomp methodology for uncertainty calculation. Additionally, the power used (16 next-generation fuel, developed jointly by Westingho Nucleares do Brasil (INB)).

4. Regulatory Independent Angra 2 LB-LOCA Analys

The independent calculation included the LB-LOCA calculation with evaluation with the CIAU method (code with capability of internal a

In this application, the CIAU method used UMAE methodology propagation of code output error and does not rely on statistic calculation comparison and are extrapolated to get uncertainty. Th from 32 experimental transients that were calculated by Pisa Unive

The independent LB-LOCA calculation activities were planned with best-estimate analysis: a qualified nodalization development (st reference-case calculation, uncertainty evaluation, and compariso studies and in the uncertainty analysis.

A “fictitious” 3D nodalization of the reactor pressure vessel was of the upper plenum test facility experiments [35]. Two main nod studies, characterized by:

(i) nonuniform upper plenum behavior, pursuing the noda analysis, top-down flow allowed only in the determined breakth
(ii) uniform upper plenum behavior with top-down flow allow the worst conditions for core cooling inside the hydraulic hot fuel assembly from the average core region.

After defining a reference calculation and performing the sensitivity the one without cross-flow simulation between the hot fuel asser that might bring undue conservatism in the results. The one consi be the reference case if experimental data was available to establ the a2n04x run, these coefficients were established through engine use of S-RELAP5 code in the Angra 2 FSAR LB-LOCA analysis co dimensional treatment added to the hydrodynamic field equations.

Figure 2 shows a comparison of the reference calculation result

(PCT) for the “base case”. In the FSAR analysis, this “base cas
the nominal condition for the uncertainty analysis. This uncertainty
generated by using Monte Carlo to combine uncertainties from the
case for the determination of the calculation-design matrix used
Also, the “base case” is the reference case where the effects of t

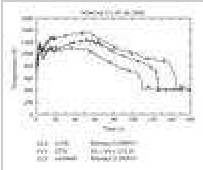

Figure 2: Cladding temperature of the hot rod

The comparison of the PCT from the “base case” and the “refe
higher value observed in independent calculation result. In the ca
removal of conservatism of assuming no cross flow to the hot ch
outcome confirms the importance of assessing, by using experime
considered.

In the independent regulatory calculation, automatic uncertainty b
and rod surface temperature at 2/3 of the core active height are
results of the application. Figure 3 shows the result for PCT.

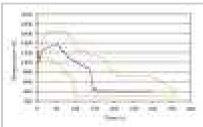

Figure 3: Uncertainty bands for rod surface te

The number of experiments, which were used to derive code uncer
study has been performed to confirm the results obtained from thi
that the impact of an assigned input parameter upon the results is

A comprehensive-sensitivity study has been carried out including
main nodalizations, single parameters are varied in each code run
“fuel”, “nodalization”, “loop hydraulics”, “PSA and ECCS”
performed runs was 112.

Thefirstseries aims at confirming the influence of selected input
and showing the importance of nodalization upon the same predi
Code runs with single change of input parameters and with real
uncertainty evaluation. Examples of input parameters varied, at o
conductivity, gap conductance), loop hydraulics (critical flow moc
bypass flow), nodalization (upper-plenum pressure drop, counter
(loss of offsite power delay, components actuation), and neutroni
is shown in Figure 4 where the envelope of all the considered calcu

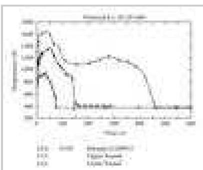

Figure 4: Angra 2 NPP LBLOCA sensitivity stu
temperature Envelope uncertainty evaluation.

The second series aims at determining boundary values for PC
considered in the first series of calculations, are selected and vari
parameters are UO2 conductivity, break-discharge coefficient, EC
conductance. The ranges of variations are maximized. These code
the uncertainty (see Figure 5).

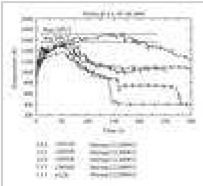

Figure 5: Angra-2 NPP LBLOCA sensitivity stu
Labels XXX through VVV representing code r
input parameters.

The parameter ΔPCT is defined as the difference between the PCT
from the generic sensitivity run. The dispersion of results for ΔPCT
an overall picture of the influence of nodalization upon predictio
upon the predicted scenario.

The following valuable results were obtained.

(i) The upper and lower uncertainty bands from the env
compared with the CIAU uncertainty bands in Figure 3. There
supported by the outcome of the sensitivity study.

(ii) The uncertainty ranges predicted by CIAU, resulting fron
FSAR, are comparable.

The adopted noding scheme, that is, the nodalization, has be
nodalization features affect the prediction of the safety relevant
"sensitivity" runs, and the use of the outcomes from the unc
designed assessed code, having at the basis a fictitious 3D mode
choices. These choices have been proven to impact noticeably th
suitable experimental evidence.

Results from a best-estimate code prediction are largely affecte
demonstration of the nodalization quality at the "steady state" a
meaningful conclusions about the safety performance of the conce
the hot leg injection, a decisive importance is revealed by the uppe

5. Conclusions

As described in the previous sections, when using a realistic
approaches have been used in the licensing arena to demonstrate

Besides the different approaches, the regulators are aware of the
therefore, further actions should be required even after a methodo

The Brazilian regulatory body is monitoring these activities and it
independent regulatory calculation is recognized once again as a
licensing framework of a realistic LB-LOCA analysis.

In the case of Angra 2 LB-LOCA, the independent calculation co
reviewing and assessing, and allowed to check the completeness

The use of an uncertainty methodology (CIAU) that has a differ
(Siemens) contributed to the understanding of the validity limits
FSAR. Conclusions are provided in relation to the acceptability of tl

In the case of Angra 1 LB-LOCA reanalysis for the steam-generato
methodology, the ASTRUM methodology uses a nonparametric or
criteria in 10 CFR 50.46(b) are satisfied.

The different approaches observed in the nuclear-power plants i
licensing process. For a small size regulatory body, this diversity
ECCS acceptance criteria, indicates a challenge to be faced with t
recognized experts in the use of best-estimate tools to contribute i

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