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Review Article

International Course to Support Nucleai by User Training in the Areas of Scaling, Uncertainty, and 3D Thermal-Hydraulics Kinetics Coupled Codes: 3D S.UN.COP Se

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Abstract

Thermal-hydraulic system computer codes are extensively used wi
regulatory bodies, nuclear power plant designers, vendors, and
represents a source of uncertainty that can influence the resul
commonly known as the "user effect" and stems from the limit
limited capability of the analysts to use the codes. Code user trai
for reducing the variation of results caused by the application of t
systematic approach to training code users who, upon comple
calculations making the best possible use of the capabilities of bes
at contributing towards solving the problem of user effect. In add

main features of the 3D S.UN.COP (scaling, uncertainty, and 3D
particular emphasis is given to the areas of the scaling, uncertainty

1. Introduction

A wide range of activities has recently been completed in the ar
considerable research efforts. Problems have been addressed, sc
upon on international ground. These include the need for best-
qualification process [3, 4], the proposal for nodalization quali
quantitative accuracy evaluations [5]. Complex uncertainty metl
study at USNRC [6]. This study attempted, among other things
definition) on code results. An international study aiming at the
uncertainty methodologies has been completed [7].

More recently (during the period 1997–1999), the IAEA (Internati
consistent with its revised Nuclear Safety Standards Series [8] tha
power plants (NPPs). The report includes a number of practical
accident analysis of NPPs. These cover the selection of initiati
modeling assumptions, the preparation of input, qualification of us
The suggestions are both conceptual as well as formal and are b
accident analysis. The report covers all major steps in performing a

Within the framework of the "Nuclear Safety Standard Series"
analysis has been addressed. The need for user qualification a
systematic training of analysts was emphasized as being crucial fo
training, in particular, have been specified in the following:

(i) practical training on the design and operation of the plar
(ii) software specific training;
(iii) application specific training.

Training on the phenomena and methodologies is typically provi
considered sufficient. Furthermore, training on the specific applica
level, whereas practical training on the design and operation of the
models. Software specific training is important for the effective use
requires the involvement of a strong support group that shares its
supervision and review. Training at all three levels ending with exa
the training. Such a procedure is considered a step in the directio
applicable to an international basis.

Based on the above considerations and facts, the paper outlines t
the user's effect in Section 2, provides a proposal for a perman
and gives a tangible example of user-training-course (i.e., 3D S.
application of best-estimate codes emphasizing scaling, best-estim
analyses, in Section 4.

2. Thermal-Hydraulic Codes and Code Users

2.1. Role and Relevance of Code User

The best estimate thermal-hydraulic codes used in the area of nuc
sophistication. Their capabilities to predict accidents and transien

over the past years as a result of large research efforts and c
provided that they are used by competent analysts.

Best estimate system codes (RELAP, TRAC, CATHARE, or ATHLET
by utilities, licensing authorities, research organizations includi
technical support organizations. The objectives of using the code
safety assessment to simply understanding the transient behavior
selected code must be proven to be adequate to the perform
necessary to create input to the selection of the noding solutions a
11].

The role of the code user is extremely relevant: experience with
(ISPs) has shown the dominant influence of the code user on the f
has not been achieved. It has been observed previously that

(i) the user gives a contribution to the overall uncertai
calculation results;
(ii) in the majority of cases, it is impossible to distinguish
“nodalization inadequacy,” “physical model deficiencies,”
and “computer/compiler effect;”
(iii) “reducing the user effect” or “finding the optimum n
that removes the need to assess the uncertainty.

Performing an adequate code analysis or assessment involves two

(1) *Code adequacy*. The adequacy demonstration process m
used outside its assessment range, when changes are made
applications where different phenomena are expected. The im
analyses must be thoroughly reviewed to ensure that the
phenomena that are being observed.
(2) *Quality of results*. Historically the results of code predicti
data gathered from applicable scaled test facilities, have re
reliability and their practical usefulness. Discrepancies betwe
attributed to model deficiencies, approximation in the num
nodalization inadequacies, imperfect knowledge of boundary
input deck, and to “user effect." In several ISPs sponsored
and Development), several users modeled the same experim
results varied widely, regardless of the code used. Some of th
approach as well as to a general lack of understanding of both

The two items are the main aspects, both related to the code us
framework of the code and nodalization. The second aspect is dire
as User Effect.

2.2. User Effect

Complex systems codes such as RELAP5, CATHARE, TRAC, and A
misapplication (e.g., not using the countercurrent flow-limiting mo
users (e.g., inputting the incorrect length of a system componen
approach the analysis of a problem in the same way and conse
problem solution. The cumulative effect of user community memb
code for a well-defined problem with rigorously specified boundary
1).

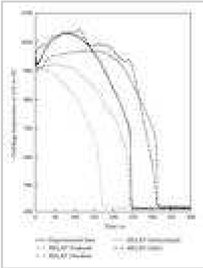

Figure 1: User effect: different results for tl
different users adopting the same code and BI(

The following are some of the reasons for the user effects.

(i) Code use guidelines are not fully detailed or comprehens
(ii) Based on the current state of the art, the actual 3D plan zones; these complex 3D geometries are suitable for differ assigned reactor vessel part is modeled differently by diffe 1dimensional code modules, a number of empirical models for separators, are specified by the users, sometimes based introducing additional inaccuracies.
(iii) Experienced users may overcome known code limitatio deck.
(iv) Problems inherent to a given code or a particular fac consideration and modeling of local pressure drop coefficients, improved solutions. This has been traditionally done to con steady-state qualified models to transient conditions, and lack typical nuclear reactor conditions). Furthermore, specific effect losses might exacerbate the user effect.
(v) The increasing number of users performing analysis understanding of the code capabilities and limitations leads t obtain a stable steady state by the user prior to the initiation o
(vi) A nonnegligible effect on code results comes from the c code selected by the user; this remains true for very recent co
(vii) Error bands and the values of initial and boundary condi defined; this ambiguity is used to justify inappropriate model n
(viii) Analysts lack complete information about facilities befor unqualified data.
(ix) Although the number of user options is thought to be re are several models and correlations for the user to choose. Th as pressure loss coefficients, manometric characteristics, effic well defined.
(x) Most codes have algorithms to adjust the time step cont minimize run time. However, users are allowed to change the smaller time steps for a given period of the transient. If the p the result will vary significantly with the time step size.
(xi) Quality assurance guidelines should be followed to che input despite the automatic consistency checks provided by the

Typical examples of user and other related effects on code calc several CSNI reports (e.g., ISP-25, ACHILLES reflooding test; LOI Feed-Water test; ISP-26 on LSTF 5% cold-leg-break loss-of-coola LOCA) and based on these outcomes different organizations have order to reduce the user effects.

The misapplication of the system code should be elimin

(i) The misapplication of the system code should be elimin detailed code description and by relevant code user guidelines.
(ii) Errors should be minimized: any analysis of merit shoul minimize or eliminate errors. In a sense, the mis-application of
(iii) The user community should preferably use the same c rors and treatment of arithmetic operations are as-sumed the s
(iv) The system code should preferably be used by a relative
(v) The problem to be analyzed should be rigorously s conditions, and boundary conditions should be clearly specified

Within the defined framework, the user effect can be quantified an

(i) the flexibility of the system code. An example is the fle nent such as the steam generator: for instance, the TRAC c steam generators whereas a steam generator model creat components such as PIPE and BRANCH; consequently, there a each requiring a decision, when a RELAP5 steam generator generated model of the same component is being defined;
(ii) the practices used to define the nodalization and to ens context, the code validation process, the nodalization qualific evaluation are necessary steps to reduce the possibility of proc

3. Permanent User Training Course for System Code

As a follow-up to the specialists meeting held at the IAEA in Septe the Jožef Stefan Institute, Ljubljana, jointly presented a Propos System Code Users [14]. It was recognized that such a course wo for current code users and a means for current code users to "permanent" stepwise approach to user training.

As a follow-up to the massive work conducted in different organiz the code user. As a first step, the kind of code user and the leve discussed.

3.1. Levels of User Qualification

Two main levels for code user qualification are distinguished in the

(i) code user, level "A" (LA);
(ii) responsible for the calculation results, level "B" (LB).

Two levels should be considered among LB code users to distingui are detailed hereafter for the LA grade only; these must be inten the LB and the LBS grades. The main difference between LA and L a system code; for the LB and the LBS grades, this can be fixed in LA grade. In such a context, any calculation having an impact in t LB (or LBS) code user and performed by a different LA or LB (or LE

3.2. Requisites for Code User Qualification

3.2.1. LA Code User Grade

The identification of the requisites for a qualified code user deriv qualified system code calculation: a system code is one of the coc principle includes the uncertainty analysis. The starting conditi knowledge of nuclear power plants and reactor thermal hydraulics the “Laurea” in Italy, etc.).

The requisites competencies for the LA grade code user are in the

(A) Generic code development and assessment processes:

Subarea (*A1*): conservation (or balance) equations in the UVUT(UP), Drift Flux, 1D, 3D, 1-field, Multifield, [2], condu Theory and Neutron Kinetics approximation, constitutive (c special components (e.g., pump, separator), material pro control systems, numerical methods, general structure of a
Subarea (*A2*): developmental assessment, independent ass Validation Matrix [3], and Integral Test (ITF) Code Valida Matrices.

(B) Specific code structure:

Subarea (*B1*): structure of the system code selected by the system, special components, material properties, numerical
Subarea (*B2*): structure of the input; examples of user choi

(C) Code use-Fundamental Problems (FP):

Subarea (*C1*): definition of Fundamental Problem (FP): si available or less. Examples of code results from applications (e.g., neutronics, thermal hydraulics, and numerics);
Subarea (*C2*): the LA code user must deeply analyze characterizing the effects of nodalization details, time step a nodalization starting from a supplied data base or prob compare the results of the reference test case with data (solution), if available; to run sensitivity calculations; and to an assigned format).

(D) Basic Experiments and Test Facilities (BETF):

Subarea (*D1*): definition of Basic Experiments and test faci of an individual phenomenon or of an individual quantity necessarily connected with the NPP. Examples of code resul
Subarea (*D2*): the LA code user must deeply analyze characterizing the effects of nodalization details, time step other code-specific features.

(E) Code use-Separate Effect Test Facilities (SETF):

Subarea (*E1*): Definition of Separate Effect Test Facility ensemble of components) or a phenomenon (or an ensemb Details about scaling laws and design criteria. Examples of c
Subarea (*E2*): The LA code user must deeply analyze at le characterizing the effects of nodalization details, time step and other code-specific features.

(F) Code use-Integral Test Facilities (ITF):

definition of Integral Test Facility (ITF): test facility

Subarea (*F1*): definition of Integral Test Facility (ITF): te
NPP is addressed. Details about scaling laws and design cr
related experimental programs. ISPs activity. Examples of c
Subarea (*F2*): the LA code user must deeply analyze at le
characterizing the effects of nodalization details, time step s
other code-specific features.

(G) Code use-Nuclear Power Plant transient Data:

Subarea (*G1*): description of the concerned NPP and of the
and ECC systems. Examples of code results from applicatior
Subarea (*G2*): the LA code user must deeply analyze at l
characterizing the effects of nodalization details, time step s
other code-specific features.

(H) Uncertainty Methods including concepts like nodalization

Description of the available uncertainty methodologies. The LA coc
field.

3.2.2. LB Code User Grade

A qualified user at the LB grade must be in possession of the same

(I) he must have a documented experience in the use of sys
(J) he must know the fundamentals of Reactor Safety and
the area of application of the concerned calculation;
(K) he must be aware of the use and of the consequenc
knowledge of the licensing process.

3.2.3. LBS Code User Grade

A qualified user at the LBS grade must be in possession of the sam

(L) he must have an additional documented experience in
years. Moreover, the LBS code user is responsible for docum
and for providing technical leadership in R&D activities.

3.3. Course Conduct and Modalities for the Achievements of

The training of the code user requires the conduct of lectu
examination, while for the senior code user, only a review of d
foreseen. The code user training, including practical exercises wh
two years and covers the areas from (A) to (H).

The modalities defined in Table 1 are necessary to achieve the L
years after achieving the LB grade and following the demonstratior

Table 1: Subjects and time schedule necessar

3.4. Training Exercises

Practical exercises foreseen during the training include develop database with problem specifications. To this end, educational mat be provided with a detailed explanation of the objectives of th application of the code by the trainee at his own institution fo supervision of the course lecturers is foreseen as "homework." T for the following applications:

(i) fundamental problems including nodalization developme
(ii) basic test facilities and related experiments including no
(iii) SETFs and related experiments including nodalization de
(iv) ITF experiments with nodalization modifications; and
(v) NPP transients including nodalization modifications.

For each of the above cases, the trainee will be required to

(1) develop (or modify) a nodalization starting from the data
(2) run the reference test case;
(3) compare the results of the reference test case with da analytical solution);
(4) run sensitivity calculations;
(5) produce a comprehensive calculation report following include, for example,

(a) the description of a particular facility;
(b) the description of an experiment (including relevance
(c) modalities for developing (or modifying) the nodalizati
(d) the description and use of nodalization qualification cri
(e) qualitative and quantitative accuracy evaluation;
(f) use of thresholds for the acceptability of results for the
(g) planning and analysis of the sensitivity runs; and
(h) an overall evaluation of the activity (code capabilities, on the safety and the design of NPP, etc.).

3.5. Examination

On-site examination at different stages during the course is cons the code user training. The homework that the candidate must c includes

(A) studying the material/documents supplied by the course
(B) solving the problems assigned by the course organize reports that must be approved by the course organizers.

The on-site tests consist of four main steps that include the eva answering questions on the reports and course subjects, and dem code. Each step must be accomplished before proceeding to the su

4. 3D S.UN.COP Seminars: Follow-up of the Proposa

4.1. Background Information about 3D S.UN.COP Trainings

The 3D S.UN.COP (Scaling, Uncertainty, and 3D coupled code c

knowledge, and experience from recognized international experts
code calculations in nuclear reactor safety technology to analysts w

The training (http://dimnp.ing.unipi.it/3dsuncop) is open to rese
academic institutions, regulatory authorities, national laboratories
into three parts and participants may choose to attend a one-, two
to the background information including the theoretical bases for
devoted to the practical application of the methodologies and to t
week is dedicated to the user qualification problem through the h
final exam. From the point of view of the conduct of the trainir
expert teaching, and by hands-on-application. More than thirty scie
the seminars, presenting theoretical aspects of the proposed me
examination. A certificate of qualified code user is released to
problems during the exams.

The framework in which the 3D S.UN.COP seminars have been d
roles of two main international institutions (OECD and IAEA) and
regulatory body of other countries) to address the problem of us
programs and produced documents. Figure 3 depicts how the
maintenance and advancements through the qualification of pers
industries by means of teaching by very well-known scientists belo

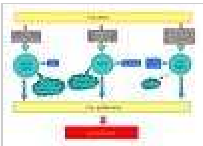

Figure 2: 3D S.UN.COP framework to address

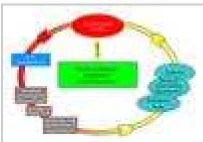

Figure 3: 3D S.UN.COP Loop of benefits.

Seven training courses have been organized up to now and were su

(i) The University of Pisa (Pisa, Italy), 5 – 9 January 2004 (6
(ii) The Pennsylvania State University (University Park, PA, U
(iii) The University of Pisa (Pisa, Italy), 14 – 18 June 2004 (1
(iv) The University of Zagreb (Zagreb, Croatia), 20 June – 8 J
(v) The Technical University of Catalonia (Barcelona, Spain),
(vi) The "Autoridad Regulatoria Nuclear (ARN)," the "Cor
"Nucleoelectrica Argentina S.A (NA-SA)," and the "Univer
Argentina), 2 October – 14 October 2006 (37 participants); anc
(vii) The Texas A&M University (College Station, Texas, USA)

4.2. Objectives and Features of the 3D S.UN.COP Seminar Tr

The main objective of the seminar activity is the training in safety
nuclear technology. The training is devoted to the promotion and u
approach to the use of computer codes for accident analysis. The r

(i) to transfer knowledge and expertise in Uncertainty Met

3D Coupled Code Applications;
(ii) to diffuse the use of international guidance;
(iii) to homogenize the approach in the use of computer
CATHENA, PARC, RELAP/SCDAP, MELCOR, and IMPACT) for acc
(iv) to disseminate the use of standard procedures for qua
(e.g., through the application of the UMAE "uncertainty metho
(v) to promote best estimate plus uncertainty (BEPU) met
through the presentation of the current industrial application
aspects of the deterministic and statistical uncertainty me
propagation of output errors (called CIAU "code with the cap
22]);
(vi) to spread available robust approaches based on BEPU m
(vii) to address and reduce user effects; and
(viii) to realize a meeting point for exchanges of ideas amor
Industry, Regulatory Authorities, and International Institutions

The main features of the seminar course are identified as follows.

(i) *The practical use of a mix of different codes*. The use of
basis for code assessment and for the acceptability of code res
(ii) *The exam*. Exams were in the past courses (very) well
possibility to show their expertise and to demonstrate the effor
(iii) *The practical use of procedures for nodalization qualific*
qualifying nodalization (i.e., input) can be directly applied in th
(iv) *The practical use of procedures for accuracy quantificati*
quantifying qualitatively and quantitatively the accuracy (i
calculated data) constitutes a key point for the acceptability of
(v) *The "joining" between BE codes and uncertainty eva*
licensing process is worthwhile for predicting more "realistic
larger safety margins.
(vi) *The large participation of very well-known international*
international guidance are promoted through lectures preser
institutions and countries.

4.3. Scientific and Technological Areas Presented at the 3D S

As the acronym 3D S.UN.COP implies, the following three scientifi
addressed during the course.

(1) Scaling analysis.
(2) Best estimate plus uncertainty analysis.
(3) Three-dimensional coupled code analysis.

Brief descriptions of each topic are given hereafter.

4.3.1. Scaling Analysis

Scaling is a broad term used in nuclear reactor technology, as
hydraulics. In general terms, scaling indicates the need for the pr
prototype. The model and the prototype are typically characteri
adopted materials, including working fluids, and different ranges of

Therefore, the word "scaling" may have different meanings in d scaling process, based upon suitable physical principles, aims at expected in a NPP transient scenario and phenomena measured in by numerical tools qualified against experiments performed in s owing to limitations of the fundamental equations at the basis of important source of uncertainties in code applications and may env

Three main objectives can be associated to the scaling analysis:

(i) the design of a test facility,
(ii) the code validation, that is, the demonstration that the c
(iii) the extrapolation of experimental data (obtained into an

In order to address the scaling issue, different approaches have be

(i) fluid balance equation, deriving nondimensional paramet
(ii) semi-empirical mechanistic equations, deriving non-dime
(iii) to perform experiments at different scales (very expensi
(iv) to develop, to qualify, and to apply codes showing their

The first item recalls a typical approach based on a theorem (determining the number of independent nondimensional groups n physical relationship among *n* variables, which can be expressed into a relationship among $(n-m)$ independent dimensionless grou dimensionless groups pi-groups and identified them as Π_1, Π_2, Π_3 reduces to a dimensionless functional equation of the form

$$\Pi_1 = f(\Pi_2, \Pi_3, \ldots, \Pi_n$$

The second item implies the definition of non-dimensional para empirical way some dependency, for example, from consideratic groups are defined similar to the pi-groups. It should be remindec valid for a restricted range thus also the dimensionless parameters

Performing experiment at different scale (third item) might be a v experiments should be conducted to cope with the wide range of t are affected by peculiarity related to the typical dimension of a tes

The last proposal to solve the scaling problem (fourth item) is to a a system code, to qualify it against experimental data, to prove t such code to predict the same relevant phenomena that are exp performed at different scale.

4.3.2. Best-Estimate Plus Uncertainty Analysis

In the past, large uncertainties in the computer models used fo been compensated using highly conservative assumptions. The lo one of the main examples about this approach. Conservative ana level of knowledge in the 1970s and it is based on the variation o code, availability of components and systems, and initial and bo results relative to specified acceptance criteria. However, the res (e.g., unrealistic behavior may be predicted or order of events ma results. In addition, significant economic penalties, not necessaril as consequence of the unknown level of used conservatism. As a recommended (e.g., in [23], however it is still mandatory in the U

US NRC 10 Code of Federal Regulations 50 (10 CFR 50) [24]) and
rather than "conservative" approaches can be identified.

By definition, a best estimate (BE) analysis (the term "best
"realistic") is an accident analysis which is free of deliberate pes
is characterized by applying best estimate codes along with nom
boundary conditions. However, notwithstanding the important ach
predictions of the best estimate system codes are not exact but re

(i) The assessment process depends upon data almost alwa
full power reactors.
(ii) The models and the solution methods in the codes are
the physics are not considered.

Consequently, the results of the code calculations may not be app
a NPP during postulated accident scenarios. Therefore, best
supplemented by proper uncertainty evaluations in order to
uncertainty" (BEPU) was coined for indicating an accident analysis

(1) is free of deliberate pessimism regarding selected accept
(2) uses a BE code, and
(3) includes uncertainty analysis.

Thus the word "uncertainty" and the need for uncertainty evalua
and, at least, the following three main reasons for the use of uncer

(i) *Licensing and safety*: if calculations are performed
uncertainties, a "relaxation" of licensing rules is possible
margins can be obtained.
(ii) *Accident management*: the estimate of code uncertain
emergency response guidelines.
(iii) *Research prioritization*: the uncertainty analysis can hel
the most improvement (code development and validation bec
of experimental tests are most needed.

Development of the BEPU approach has spanned nearly the las
evaluation of various BEPU methods—uncertainty methods study
OECD/NEA [7] during 1995–1998 already concluded that the
circumstances and uncertainty analysis is needed if useful conclus
Similar international projects are in progress under the admi
methods uncertainty and sensitivity evaluation [25]) and IAEA
uncertainties in best estimate accident analyses) to evaluate t
methods.

Notwithstanding the above considerations, it is necessary to note
conservative one depends upon a number of conditions that are
available computational tools, the expertise inside the organizati
amount of data and the related details can be much different in th
or the requests from the national regulatory body (e.g., in US lic
as an alternative to Appendix K conservative approach defined
Emergency Core Cooling System (ECCS) performance obtained th
conservative analyses are still widely used to avoid the need of
data or simply to avoid the burden to change approved code and/o

4.3.3. Three-Dimensional Coupled Code Analysis

The advent of increased computing power with the present av
coupling of large codes that have been developed to meet spe
calculations for partial anticipated transients without scram (ATWS
study mixing in three-dimensions (particularly for passive em
computational tools. The range of software packages that are des
systems analysis codes includes

(i) multidimensional neutronics,
(ii) multidimensional computational fluid dynamics (CFD),
(iii) containment,
(iv) structural mechanics,
(v) fuel behavior, and
(vi) radioactivity transport.

There are many techniques for coupling advanced codes. In essen
two or more codes only communicate after a number of time step
time step to time step. Whether a loose coupling or a tight couplin
are being modeled and analyzed. For example, the need to consid
the secondary fluid during a relatively slow transient does not requ
not have to communicate time step by time step. In contrast, the
where a portion of the core is modeled in great detail using a CF
using a system analysis code would require tight coupling if the tv
occur during a NPP transient. Indeed, since CFD codes generally c
behavior due to the exceedingly large computer resource requirem
somewhat rapid transient in an NPP core region is via close coupl
NPP system. Thus the system analysis code provides boundary con
identified.

4.4. The Structure of the 3D S.UN.COP

The seminar is subdivided into three main parts, each one with a p
between lectures, computer work, and model discussion have show
a high level. The duration of the individual sessions varied substa
and the training needs of the participants.

(i) The first week (titled “fundamental theoretical aspects”) is fu
the proposed methodologies. The following technical sessions (with
main topics hereafter listed.

(a) *Session I: System codes: evaluation, application, modeli*

    (1) Models and capabilities of system code models,
    (2) Development process of generic codes and developme
    (3) Scaling of thermal-hydraulic phenomena,
    (4) Separate and integral test facility matrices.

(5) *Session II: International standard problems*

    (1) Lesson learned from OECD/CSNI ISP,
    (2) Characterization and Results from some ISP.

(c) *Session III: Best estimate in system code applications an*

    IAEA safety standards.

(1) IAEA safety standards,
(2) Origins of uncertainty,
(3) Approaches to calculate uncertainty,
(4) User effect,
(5) Evaluation of safety margins using BEPU methodologi
(6) International programs on uncertainty (UMS [7] and I

(d) *Session IV: Qualification procedures*

(1) Qualifying, validating, and documenting input,
(2) The feature of UMAE methodology,
(3) Description and use of nodalization qualification criter
(4) Use of thresholds for the acceptability of results for th
(5) Qualitative accuracy evaluation,
(6) Quantitative accuracy evaluation by fast Fourier trans

(e) *Session V: Methods for sensitivity and uncertainty analy*

(1) GRS statistical uncertainty methodology [27],
(2) CIAU method for uncertainty evaluation,
(3) Adjoint sensitivity analysis procedure (ASAP) and g procedures for sensitivity analysis [28, 29],
(4) Comparison of uncertainty methods with code scali methodology [6].

(f) *Session VI: Relevant topics in best estimate licensing ap*

(1) Best estimate approach in the licensing process in sev

(g) *Session VII: Industrial application of the best estimate p*

(1) Westinghouse realistic large break LOCA methodology
(2) AREVA realistic accident analysis methodology [17],
(3) GE technology for establishing and confirming uncerta
(4) Best estimate and uncertainty (BEAU) for CANDU rea
(5) UMAE/CIAU application to Angra-2 licensing calculatic

(ii) The second week (titled "Practical Applications and Hands-on aspects of the proposed methodologies and to the hands-on tra CATHENA, RELAP5 USNRC, RELAP5-3D, TRACE, PARCS, RELAP/SC are presented covering the main topics hereafter listed.

(a) *Session I: Coupling methodologies*

(1) Cross-section generation: models and applications,
(2) Coupling 3D neutron-kinetics/thermal-hydraulic codes
(3) Uncertainties in basic cross-section,
(4) CIAU extension to 3D NK-TH.

(b) *Session II: Coupling code applications*

(1) PWR-BWR-WWER analysis,
(2) BWR stability issue,
(3) WWER containment modeling,
(4) System boron transport, boron mixing and validation.

Session III: CIAU/UMAE applications

(c) *Session III: CIAU/UMAE applications*

(1) Key applications of CIAU methodology,
(2) Example of code results from application to ITF (LOFT Type),
(3) “PSB Facility” counterpart test,
(4) Bifurcation study with CIAU,
(5) CIAU software.

(d) *Session IV: Computational Fluid Dynamics Codes*

(1) The role and the structure of the CFD codes,
(2) CFD simulation in nuclear application: needs and appl

Each of the *parallel hands-on trainings on numerical codes* consist topics:

(3) structure of specific codes,
(4) numerical methods,
(5) description of input decks,
(6) description of fundamental analytical problems,
(7) analysis and code hands-on training on fundamental p problems deal with boiling channel, blow-down of a pressurizec
(8) Example of code results from applications to ITFs (LOFT,

(iii)The third week (titled “Hands-on Training for Advanced Users users addressing the user effect problem. The participants are di\ the training from one teacher. The applications of the proposed through the BETHSY ISP 27 (small break LOCA) and LOFT L2–5 (using several tools (RELAP5, WinGraf, FFTBM, UBEP, CIAU, etc covered:

(1) modalities for developing (or modifying) the nodalization
(2) plant accident and transient analyses,
(3) examples of code results from application to a NPP (PWR
(4) Code hands-on training through the application of syster

A final examination on the lessons learned during the seminar is de

(i) Written Part: questions about the topics discussed durir each participant and to each group.
(ii) Application Part: two types of problems are propos respectively.

(1) *Detection of Simple Input Error:* Each participant rece the correct RELAP5 nodalization input deck, and the restar input error. Each participant will identify the error.
(2) *Detection of Complex Input Error:* Each group receives correct RELAP5 nodalization input deck, and the restart file error. Each group will identify the error.

Evaluation reports are submitted in a written form containing between results of the reference calculation and results from tl over two will be correctly solved to obtain the certificate.
(iii) Final Discussion: each participant takes an oral examina own group) with the examiners. General questions related to

are asked to the participants.

A certificate of type “LA Code User Grade” (see Table 1) like the that successfully solved the assigned problems.

Figure 4: 3D S.UN.COP “LA Code User Grade

4.5. 3D S.UN.COP 2007 at Texas A&M University (Texas, US/

The 3D S.UN.COP 2007 was successfully held at the Texas A&I February 9th with the attendance of 26 participants coming (universities, vendors, national laboratories, and regulatory bodie different institutions) were involved in the organization of the sem methodologies and holding the training and the final examination.

Table 2: 3D S.UN.COP 2007.

All the participants achieved a basic capability to set up, run, and code (e.g., RELAP5) through the application of the proposed procedures.

At the end of the seminar a questionnaire for the evaluation of tl them very positively evaluated the conduct of the training as can b

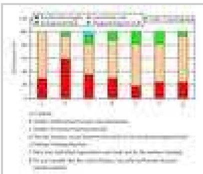

Figure 5: Design and conduct of the seminar t

5. Conclusions

An effort is being made to develop a proposal for a systematic ap training at the course venue, including a set of training se approximately two years. In addition, the specification and assignn their home institutions, with continuous supervision from the traini

The 3D S.UN.COP seminars training courses constitute the follow code-user effect along with the methodologies for performing tl calculation-analyses are the main topics discussed during the coı training demonstrated an increase in their capabilities to develop

qualitative and quantitative accuracy evaluation. It is expected
accurate, reliable, and efficient simulation models applying the pro
code calculations and for the evaluation of the uncertainty.

List of Abbreviations

ASAP:	Adjoint sensitivity analysis procedure
ATWS:	Anticipated transients without scram
BE:	Best estimate
BEAU:	Best estimate and uncertainty
BEMUSE:	Best estimate methods uncertainty and sensitivity e
BEPU:	Best estimate plus uncertainty
BETF:	Basic experiments test facilities
BoP:	Balance of plant
BWR:	Boiling water reactor
CFD:	Computational fluid dynamics
CFR:	Code of federal regulations
CIAU:	Code with the capability of Internal Assessment of U
CSAU:	Code scaling, applicability and uncertainty evaluatic
CSNI:	Committee on the Safety of Nuclear Installations
ECCS:	Emergency core cooling system
EVET:	Equal velocities, equal temperatures
FFTBM:	Fast fourier transform-based method
FP:	Fundamental problem
GASAP:	Global adjoint sensitivity analysis procedure
HEM:	Homogeneous equilibrium model
IAEA:	International Atomic Energy Agency
ISP:	International standard problems
ITF:	Integral test facilities
LA:	Level A degree (terminology used in the certificate)
LB:	Level B degree (terminology used in the certificate)
LBS:	Level B Senior degree (terminology used in the cert
LOCA:	Loss-of-coolant-accident
NEA:	Nuclear Energy Agency
NK:	Neutron-kinetics
NPP:	Nuclear power plants
OECD:	Organization for Economic Cooperation and Develop
PWR:	Pressurized water reactor
SETF:	Separate effect test facility
TH:	Thermal-Hydraulic
UBEP:	Uncertainty band extrapolation process
UMAE:	Uncertainty methodology based on acuracy extrapo
UMS:	Uncertainty methods study
US NRC:	United States Nuclear Regulatory Commission

UVUT(UP): Unequal velocities, unequal temperatures (unequal
WWER: Water-cooled water-moderated energy reactor
1D, 3D: One-dimensional, three-dimensional
3D S.UN.COP: (Training on) Scaling, Uncertainty, and 3D coupled

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