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ACQUIRED EXPERIENCE ON ORGANIZING 3D S.UN.COP: INTERNATIONAL COURSE TO SUPPORT NUCLEAR LICENSING BY USER TRAINING IN THE AREAS OF SCALING, UNCERTAINTY, AND 3D THERMAL-HYDRAULICS/NEUTRON-KINETICS COUPLEDED CODES

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ABSTRACT

Thermal-hydraulic system computer codes are extensively used worldwide for analysis of nuclear facilities by utilities, regulatory bodies, nuclear power plant designers, vendors, and research organizations. Computer code user represents a source of uncertainty that may significantly affect the results of system code calculations. Code user training and qualification represent an effective means for reducing the variation of results caused by the application of the codes by different users. This paper describes the experience in applying a systematic approach to training code users who, upon completion of the training, should be able to perform calculations making the best possible use of the capabilities of best estimate codes. In addition, this paper presents the organization and the main features of the 3D S.UN.COP (scaling, uncertainty, and 3D coupled code calculations) seminars during which particular emphasis is given to practical applications in connection with the licensing process of best estimate plus uncertainty methodologies, showing the designer, utility and regulatory approaches.

1. INTRODUCTION

A wide range of activities has been completed in the area of system thermal-hydraulics as a follow-up to considerable research efforts. Problems have been addressed, solutions to which have been at least partly agreed upon on international ground. These include the need for best estimate system codes [1, 2], the general code qualification process [3, 4], the proposal for nodalization qualification, and attempts aiming at qualitative and quantitative accuracy evaluations [5]. Complex uncertainty methods have been proposed, following a pioneering study at USNRC [6]. This study attempted, among other things, to account for user effects (see Section 2 for definition) on code results. An international study aiming at the comparison of assumptions and results of code uncertainty methodologies has been completed [7].

During the period of 1997-2003 the International Atomic Energy Agency (IAEA) developed documents consistent with its revised Nuclear Safety Standards Series that provides guidance on accident analysis of nuclear power plants (NPPs) [8-10]. The reports cover all major steps in performing accident analyses and the important role of the user's effects on the analysis has been addressed. The need for user qualification and training has been clearly recognized and the systematic training of analysts was emphasized as being crucial for the quality of the analysis results. Three areas of training, in particular, have been specified: practical training on the design and operation of the plant, software specific training, and application specific training.

Training on the phenomena and methodologies is typically provided at the university level, but cannot always be considered sufficient. Furthermore, training on the specific application of system codes is not usually provided at this level, whereas practical training on the design and operation of the plant is essential for the development of the plant models. Software specific training is important for the effective use of the individual code. Application specific training requires the involvement of a strong support group that shares its experience with the trainees and provides careful supervision and review. Training at all three levels ending with examination is encouraged for a better effectiveness of the training. Such a procedure is considered a step in the direction of establishing a standard approach that could be applicable to an international basis.

Based on the above considerations, the paper outlines the role of the code user addressing the problem of the user's effect in Section 2, provides a proposal for a permanent training course for system codes in Section 3, and gives in Section 4 an example of user-training-course (3D S.UN.COP), mostly focused on the development and application of best-estimate codes emphasizing scaling, best estimate, uncertainty, and 3D coupled code calculations analyses.

2. THERMAL-HYDRAULIC CODES AND CODE USERS

2.1. Role and Relevance of Code User

The capabilities of best estimate thermal-hydraulic system codes used in the area of nuclear reactor safety to predict accidents and transients at existing plants have substantially improved over the past years as a result of large research efforts and can be considered satisfactory for practical needs provided that they are used by competent analysts.

Best estimate system codes are used by designer/vendors of NPPs, by utilities, licensing authorities, research organizations including universities, nuclear fuel companies, and by technical support organizations. The objectives of using the codes may be quite different, ranging from design or safety assessment to simply understanding the transient behavior of a simple system. However, the application of a selected code must be proven to be adequate to the performed analysis. Many aspects from the design data necessary to create input to the selection of the noding solutions and the code itself are the user's responsibility [11–13].

The role of the code user is extremely relevant: experience with large number of International Standard Problems (ISP) has shown the dominant influence of the code user on the final results and the goal of reduction of user effects has not been achieved. It has been observed previously that the user gives a contribution to the overall uncertainty that unavoidably characterizes system code calculation results. In the majority of cases, it is impossible to distinguish among uncertainty sources like "user effect," "nodalization inadequacy," "physical model deficiencies," "uncertainty in boundary or initial conditions," and "computer/compiler effect".

Performing an adequate code analysis or assessment involves two main aspects:
(1) *Code adequacy*. The adequacy demonstration process must be undertaken by a code user when a code is used outside its assessment range, when changes are made to the code, and when a code is used for new applications where different phenomena are expected.
(2) *Quality of results*. The results of code predictions, when compared with experimental data gathered from applicable scaled test facilities, have revealed inadequacies raising concerns about code reliability and their practical usefulness. Discrepancies between measured and calculated values were attributed to model deficiencies, approximation in the numeric solutions, computer, and compiler effects, nodalization inadequacies, imperfect knowledge of boundary and initial conditions, unrevealed mistakes in the input deck, and to "user effect."

The two items are the main aspects, both related to the code user. The first aspect is included in the qualification framework of the code and nodalization. The second aspect is directly related to the user choices generally referred to as User Effect.

2.2. User Effect

Complex systems codes such as RELAP5, CATHARE, TRAC, and ATHLET have many degrees of freedom that allow misapplication and errors by users. Even two competent users will not approach the analysis of a problem in the same way and consequently, will likely take different paths to obtain a problem solution. The cumulative effect of user community members to produce a range of answers using the same code for a well-defined problem with specified boundary and initial conditions is the user effect (see Figure 1).

The following are some examples of the reasons for the user effects:
(i) Code use guidelines are not fully detailed or comprehensive.
(ii) Based on the current state of the art, the actual 3D plant geometries are usually modeled using several 1D zones; these complex 3D geometries are suitable for different modeling alternatives.
(iii) Experienced users may overcome known code limitations by adding engineering knowledge to the input deck.
(iv) Problems inherent to a given code or a particular facility have been dealt with over the years by the consideration and modeling of local pressure drop coefficients, critical flow rate multipliers, or other bias to obtain improved solutions.
(v) The increasing number of users performing analysis with insufficient training.
(vi) A non negligible effect on code results comes from the compiler and the computer used to run an assigned code selected by the user; this remains true for very recent code versions.

(vii) Although the number of user options is thought to be reduced in the advanced codes, for some codes there are several models and correlations for the user to choose.

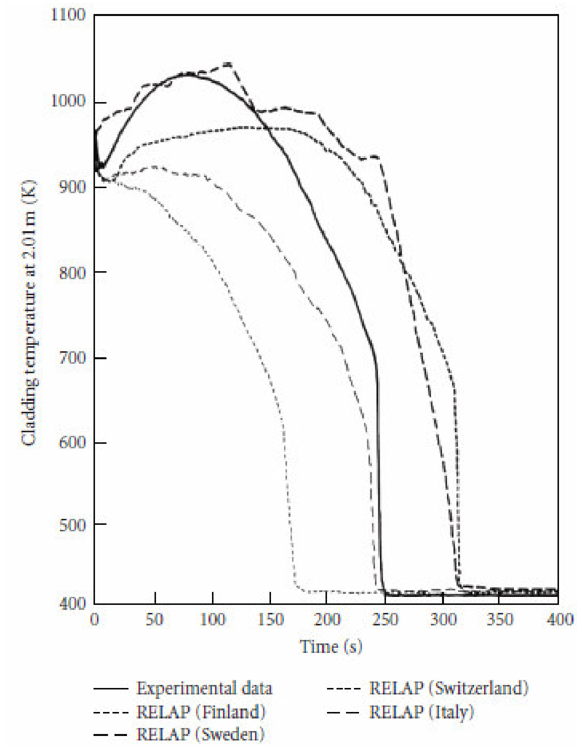

Figure 1: Different results for cladding temperature (ISP25) from different users adopting the same code and BIC.

Within the defined framework, the user effect can be quantified and be a function of the flexibility of the system code and of the practices used to define the nodalization and to ensure that a convergent solution is achieved. For instance, the TRAC code has a specific component designed to model steam generators whereas a steam generator model created using RELAP5 is constructed of basic model components such as PIPE and BRANCH; consequently, there are more degrees of freedom available to the user, each requiring a decision, when a RELAP5 steam generator model is being constructed than when a TRAC model of the same component is being defined. In this context, the code validation process, the nodalization qualification, and the qualitative or quantitative accuracy evaluation are necessary steps to reduce the possibility of producing poor code predictions [14, 15].

3. PERMANENT USER TRAINING COURSE FOR SYSTEM CODE: PROPOSAL

As a follow-up to the specialists meeting held at the IAEA in September 1998, the Universities of Pisa and Zagreb and the Jozef Stefan Institute, Ljubljana, jointly presented a Proposal for the Permanent Training Course for System Code Users [16]. It was recognized that such a course would represent both a source of continuing education for current code users and a means for current code users to enter the formal training structure of a proposed "permanent" stepwise approach to user training. As a first step, the kind of code user and the level of responsibility of a calculation result should be discussed.

3.1. Levels of User Qualification

Two main levels for code user qualification are distinguished: code user, level "A" (LA), and responsible for the calculation results, level "B" (LB). Two levels should be considered among LB code users to distinguish seniority (i.e., Level B, Senior (LBS)). Requisites are detailed hereafter for the LA grade only; these must be intended as a necessary step (in the future) to achieve the LB and the LBS grades.

3.2. Requisites for Code User Qualification

The identification of the requisites for a qualified code user derives from the areas and the steps concerned with a qualified system code calculation: a system code is one of the codes previously defined and a qualified calculation in principle includes the uncertainty analysis. The starting condition for LA code user is a scientist with generic knowledge of nuclear power plants and reactor thermal hydraulics.

The requisites competencies for the LA grade code user are in the following areas.

(A) Generic code development and assessment processes
Subarea (*A1*): conservation (or balance) equations in thermal hydraulics;
Subarea (*A2*): developmental assessment, independent assessment (Separate Effect Tests (SETF) Code Validation Matrix [3], and Integral Test (ITF) Code Validation Matrix [4]).
(B) Specific code structure
Subarea (*B1*): thermal hydraulics, neutronics, control system, special components, material properties, numerical solution;
Subarea (*B2*): structure of the input; examples of user choices.
(C) Code use-Fundamental Problems (FP)
Subarea (*C1*): definition of the Fundamental Problem: simple problems for which analytical solution may be available; different areas of the code must be concerned (e.g., neutronics, thermal hydraulics, and numerics);
Subarea (*C2*): the LA code user must deeply analyze at least three specified FPs, searching for and characterizing the effects of nodalization details, time step selection and other code-specific features; run sensitivity calculations; and to produce a comprehensive calculation report (having an assigned format).
(D) Basic Experiments and Test Facilities (BETF)
Subarea (*D1*): definition of BETF: research aiming at the characterization of an individual phenomenon or of an individual quantity appearing in the code implemented equations, not necessarily connected with the NPP.
Subarea (*D2*): the LA code user must deeply analyze at least two selected BETF, searching for and characterizing the effects of nodalization details, time step selection, error in boundary and initial conditions, and other code-specific features.
(E) Code use-Separate Effect Test Facilities (SETF)

Subarea (*E1*): Definition of SETF: test facility where a component (or an ensemble of components) or a phenomenon (or an ensemble of phenomena) of the reference NPP is simulated. Details about scaling laws and design criteria.
Subarea (*E2*): The LA code user must deeply analyze at least one specified SETF experiment, searching for and characterizing the effects of nodalization details, time step selection, errors in boundary and initial conditions, and other code-specific features.
(F) Code use-Integral Test Facilities (ITF)
Subarea (*F1*): definition of ITF: test facility where the transient behavior of the entire NPP is addressed. Details about scaling laws and design criteria. Details about existing (or dismantled) ITF and related experimental programs. ISPs activity.
Subarea (*F2*): the LA code user must deeply analyze at least two specified ITF experiments, searching for and characterizing the effects of nodalization details, time step selection, errors in boundary and initial conditions and other code-specific features.
(G) Code use-Nuclear Power Plant transient Data
Subarea (*G1*): description of the concerned NPP and of the relevant Balance of the Plant and the Emergency Core Coolant System.
Subarea (*G2*): the LA code user must deeply analyze at least two specified NPP transients, searching for and characterizing the effects of nodalization details, time step selection, errors in boundary and initial conditions and other code-specific features.
(H) Uncertainty methods (nodalization, accuracy quantification, and user effects)
Subarea (*H1*): Description of the available uncertainty methodologies.

A qualified user at the LB grade must be in possession of the same expertise as the LA grade and must have a documented experience in the use of system codes of at least 5 additional years, must know the fundamentals of Reactor Safety and Operation and Design having generic expertise in the area of application of the concerned calculation, and must be aware of the use and of the consequences of the calculation results; this may imply the knowledge of the licensing process.

A qualified user at the LBS grade must be in possession of the same expertise as the LB grade and must have an additional documented experience in the use of system codes of at least 5 additional years. The LBS code user is responsible for documenting user guidelines, methodology descriptions, and for providing technical leadership in R&D activities.

3.3. Course Conduct and Modalities for the Achievement of Code User Grades

The training of the code user requires the conduct of lectures, practical on-site exercises, homework, and examination, while for the senior code user, only a review of documented experience and on-site examination is foreseen. The code user training lasts two years and covers the areas from (A) to (H). Practical exercises foreseen during the training include development of the nodalization from the pre-prepared database with problem specifications. Extensive application of the code by the trainee at his own institution following detailed recommendations and under the supervision of the course lecturers is foreseen as "homework." On-site examination at different stages during the course is considered a condition for the successful completion of the code user training. The homework that the candidate must complete before attempting the on-site examination includes studying the material supplied by the course and solving the problems assigned by the course organizers, including the preparation of suitable reports that must be approved by the course organizers.

4. 3D S.UN.COP SEMINARS: FOLLOW-UP OF THE PROPOSAL

4.1. Background Information, Objective and Features of the 3D S.UN.COP Trainings

The 3D S.UN.COP seminar is in general subdivided into three parts and participants may choose to attend a one-, two-, or three-week course. The first week is dedicated to the background information including the theoretical bases for the proposed methodologies; the second week is devoted to the practical application of the methodologies and to the hands-on training on numerical codes; the third week is dedicated to the user qualification problem through the hands-on training for advanced user and includes a final exam. From the point of view of the conduct of the training, the weeks are characterized by lectures, code-expert teaching, and by hands-on-application. More than thirty scientists are in general involved in the organization of the seminars, presenting theoretical aspects of the proposed methodologies and holding the training and the final examination. A certificate of qualified code user is released to participants that successfully solve the assigned problems during the exams.

The framework in which the 3D S.UN.COP seminars have been designed may be derived from Figure 2, where the roles of two international institutions (OECD and IAEA) and of the US NRC (here playing the role of regulatory body of other countries) to address the problem of user effect are outlined together with the proposed programs and produced documents.

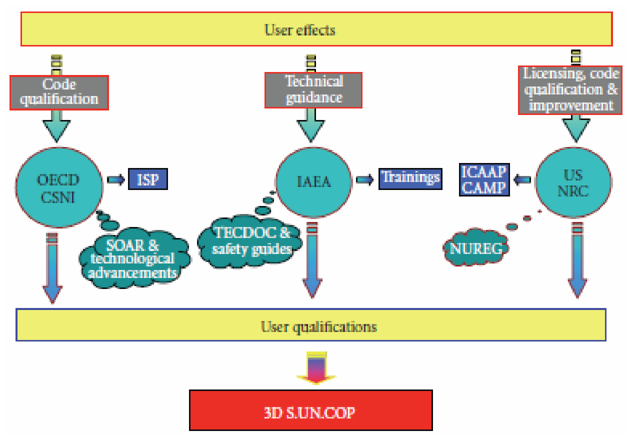

Figure 2: 3D S.UN.COP framework to address the user effect problem.

Figure 3 depicts how the 3D S.UN.COP ensures the nuclear technology maintenance and advancements through the qualification of personnel in regulatory bodies, research activities, and industries by means of teaching by very well-known scientists belonging to the same type of institutions.

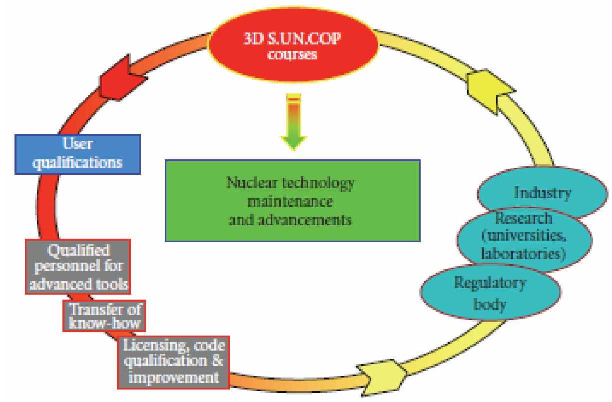

Figure 3: 3D S.UN.COP Loop of benefits.

The next 3D S.UN.COP 2012 is planning to be held at Korea Atomic Energy Research Institute - KAERI, Daejeon, South Korea 9 – 27 April, 2012. Since 2004 twelve training courses have been organized up to now, as shown in Table 1:

Table 1. 3D S.UN.COP Seminars.

Place	Date	Participants
Pisa University - Italy	5-9 Jan 2004	6
Pennsylvania State University - USA	24-28 May 2004	15
Pisa University - Italy	14-18 Jun 2004	11
University of Zagreb - Croacia	20 Jun - 8 Jul 2005	19
Technical University of Catalonia - Spain	23 Jan - 10 Feb 2006	33
Universidad Argentina De la Empresa - Argentine	2 - 14 Oct 2006	37
Texas A&M University - USA	22 Jan - 9 Feb 2007	26
McMaster University - Canada	8 - 26 Oct 2007	33
Joint Research Center EC – The Netherlands	13 - 31 Oct 2008	35
Royal Institute of Technology KTH	12 - 30 Oct 2009	35
Joint Research Center EC – The Netherlands	18 Oct - 5 Nov 2009	23
Wilmington North Carolina - USA	28 Mar - 15 Apr 2009	20

The main objectives of the seminar course are:
(i) to transfer knowledge and expertise in the Uncertainty Methodologies, Thermal-Hydraulics System Code, and 3D Coupled Code Applications;
(ii) to diffuse the use of international guidance;
(iii) to homogenize the approach in the use of computer codes for accident analysis;
(iv) to disseminate the use of standard procedures for qualifying thermal-hydraulic system code calculation (e.g., through the application of the UMAE "uncertainty methodology based on accuracy extrapolation" [17]);
(v) to promote best estimate plus uncertainty (BEPU) methodologies in thermal-hydraulic accident analysis through the presentation of the current industrial applications [18–22] and the description of the theoretical aspects of the deterministic and statistical uncertainty

methods as well as the method based upon the propagation of output errors (called CIAU "code with the capability of internal assessment of uncertainty" [23, 24]);
(vi) to spread available robust approaches based on BEPU methodology in licensing process;
(vii) to address and reduce user effects; and
(viii) to realize a meeting point for exchanges of ideas among the worlds of Academy, Research Laboratories, Industry, Regulatory Authorities, and International Institutions.

4.2. Scientific and Technological Areas Presented at the 3D S.UN.COP Seminar

Scaling analysis

The word "scaling" may have different meanings in different contexts. In system thermal hydraulics, a scaling process, based upon suitable physical principles, aims at establishing a correlation between (a) phenomena expected in a NPP transient scenario and phenomena measured in smaller scale facilities or (b) phenomena predicted by numerical tools qualified against experiments performed in small scale facilities (in connection with this point, owing to limitations of the fundamental equations at the basis of system codes, the scaling issue may constitute an important source of uncertainties in code applications and may envelop various "individual" uncertainties). Three main objectives can be associated to the scaling analysis: the design of a test facility, the code validation, that is, the demonstration that the code accuracy is scale independent, and the extrapolation of experimental data to predict the NPP behavior.

Best-estimate plus uncertainty analysis

In the past, large uncertainties in the computer models used for nuclear power system design and licensing have been compensated using highly conservative assumptions. The loss-of-coolant-accident (LOCA) evaluation model is one of the main examples about this approach. Conservative analysis was introduced to cover uncertainties at the level of knowledge in the 1970s and it is based on the variation of key components of the safety analysis (computer code, availability of components and systems, and initial and boundary conditions) in a way leading to pessimistic results relative to specified acceptance criteria. However, the results obtained by this approach may be misleading (e.g., unrealistic behavior may be predicted or order of events may be changed) and this typically leads to unphysical results. In addition, significant economic penalties, not necessarily commensurate to the safety benefits, may result as consequence of the unknown level of used conservatism. As a conclusion, the use of this approach is not longer recommended [25] (it is still mandatory in the USA for methodologies referencing the Appendix K of the 10 CFR 50 [26]).

By definition, a best estimate (BE) analysis is an accident analysis which is free of deliberate pessimism regarding selected acceptance criteria, and is characterized by applying best estimate codes along with nominal plant data and with best estimate initial and boundary conditions. However, notwithstanding the important achievements and progress made in recent years, the predictions of the best estimate system codes are not exact but remain uncertain because [7] the assessment process depends upon data almost always measured in small scale facilities and not in the full power reactors and the models and the solution methods in the codes are approximate: in some cases, fundamental laws of the physics are not considered.

Consequently, the results of the code calculations may not be applicable to give exact information on the behavior of a NPP during postulated accident scenarios. Therefore, best estimate predictions of NPP scenarios must be supplemented by proper uncertainty evaluations in order to be meaningful. The term "best estimate plus uncertainty" (BEPU) was coined for indicating an accident analysis which is free of deliberate pessimism regarding selected acceptance criteria, uses a BE code, and includes uncertainty analysis.

Thus the word "uncertainty" and the need for uncertainty evaluation are strictly connected with the use of BE codes and, at least, the following three main reasons for the use of uncertainty analysis can be identified.
(i) *Licensing and safety:* if calculations are performed in best estimate fashion with quantification of uncertainties, a "relaxation" of licensing rules is possible and a more realistic estimates of NPPs' safety margins can be obtained.
(ii) *Accident management:* the estimate of code uncertainties may also have potential for improvements in emergency response guidelines.
(iii) *Research prioritization:* the uncertainty analysis can help to identify correlation and code models that need the most improvement (code development and validation become more cost effective); it also shows what kind of experimental tests are most needed.

Development of the BEPU approach has spanned nearly the last three decades. The international project on the evaluation of various BEPU methods, Uncertainty Methods Study (UMS), conducted under the administration of the OECD/NEA [7] during 1995–1998 already concluded that the methods are suitable for use under different circumstances and uncertainty analysis is needed if useful conclusions are to be obtained from best estimate codes. Similar international projects are in progress under the administration of OECD/NEA (BEMUSE—best estimate methods uncertainty and sensitivity evaluation [27]) and IAEA (Coordinated Research Project on investigation of uncertainties in best estimate accident analyses) to evaluate the practicability, quality, and reliability of BEPU methods.

More recently, the IAEA developed a specific safety guide for nuclear power plants deterministic safety analyses [28]. This guide and the mentioned safety reports series [8-10] recommend as one of the options for demonstrating the adequate safety margins the use of best estimate computer codes with realistic input data in combination with the evaluation of uncertainties in the calculation results. Aiming at complementing these safety standards, the IAEA developed a report [29] providing more detailed information on the methods available for the evaluation of uncertainties in deterministic safety analysis for nuclear power plants and providing practical guidance in the use of these methods.

Notwithstanding the above considerations, it is necessary to note that the selection of a BEPU analysis in place of a conservative one depends upon a number of conditions that are away from the analysis itself. These include the available computational tools, the expertise inside the organization, the availability of suitable NPP data, or the requests from the national regulatory body. In addition, conservative analyses are still widely used to avoid the need of developing realistic models based on experimental data or simply to avoid the burden to change approved code and/or the approaches to get the licensing.

Three-dimensional coupled code analysis

The advent of increased computing power with the present available computer systems is making possible the coupling of large codes that have been developed to meet specific needs such as three-dimensional neutronics calculations for partial anticipated transients without scram (ATWS), with computational fluid dynamics codes, and to study mixing in three-dimensions (particularly for passive emergency core cooling systems) and with other computational tools. The range of software packages that are desirable to couple with advanced thermal-hydraulics systems analysis codes includes multidimensional neutronics, multidimensional computational fluid dynamics (CFD), containment, structural mechanics, fuel behavior, and radioactivity transport.

There are many techniques for coupling advanced codes. In essence, the coupling may be either loose (meaning the two or more codes only communicate after a number of time steps) or tight such that the codes update one another time step to time step. Whether a loose coupling or a tight coupling is required is dependent on the phenomena that are being modeled and analyzed.

4.3. The Structure of the 3D S.UN.COP Seminar

The seminar is subdivided into three main parts, each one with a program to be developed in one week. The changes between lectures, computer work, and model discussion have shown to be useful at maintaining participant interest at a high level.

(i) First week ("Fundamental Theoretical Aspects"):
Session I: System codes: evaluation, application, modeling, and scaling
Session II: International standard problems
Session III: Best estimate in system code applications and uncertainty evaluation
Session IV: Qualification procedures
Session V: Methods for sensitivity and uncertainty analysis
(1) GRS statistical uncertainty methodology [30],
(2) CIAU method for uncertainty evaluation [23],
(3) Adjoint sensitivity analysis procedure (ASAP) and global adjoint sensitivity analysis procedure (GASAP), procedures for sensitivity analysis [31],
(4) Comparison of uncertainty methods with code scaling, applicability, and uncertainty (CSAU) evaluation methodology [6].
Session VI: Relevant topics in best estimate licensing approach
(1) BE approach in the licensing process in several countries (Brazil, Germany, US, etc.).
Session VII: Industrial application of the best estimate plus uncertainty methodology
(1) Westinghouse realistic large break LOCA methodology [18],
(2) AREVA realistic accident analysis methodology [19],
(3) GE technology for establishing and confirming uncertainties [20],
(4) Best estimate and uncertainty BEAU for CANDU reactors [21],
(5) UMAE/CIAU application to Angra-2 licensing calculation [22].

(ii) Second week ("Practical Applications and Hands-on Training"): devoted to lectures on the practical aspects of the proposed methodologies and to the hands on training on numerical codes like ATHLET, CATHARE, CATHENA, RELAP5 USNRC, RELAP5-3D, TRACE, PARCS, RELAP/SCDAP, and IMPACT.

Session I: Coupling methodologies
Session II: Coupling code applications
Session III: CIAU/UMAE applications
Session IV: Computational Fluid Dynamics Codes.

(iii) Third week ("Hands-on Training for Advanced Users and Final Examination") is designed for advanced users addressing the user effect problem. The participants are divided into groups of three and each group receives the training from one teacher. The applications of the proposed methodologies (UMAE, CIAU, etc.) are illustrated through the BETHSY ISP 27 (SBLOCA) and LOFT L2–5 (large break LOCA) tests.

A final examination on the lessons learned during the seminar is designed and consists of a written part when questions about the topics discussed during the seminar are proposed and assigned both to each participant and to each group. There is also an oral examination discussing own results with the examiners. There is also an application part of the final examination with two types of problems proposed to the single participant and to the group. These are *Detection of Simple/Complex Input Error.* Each participant/group receives the experimental data of the selected transient, the correct RELAP5 nodalization input deck, and the restart file of the wrong input deck containing one simple/complex input error. Each participant/group will identify the error. At least, one problem over two will be correctly solved to obtain the certificate.

4.4. 3D S.UN.COP at Royal Institute of Technology

The 3D S.UN.COP 2009 was held at the Royal Institute of Technology KTH, with the attendance of 35 participants coming from 10 countries and 21 different institutions. About 30 scientists from 11 countries and 19 different institutions were involved in the organization of the seminars. At the end of each 3D S.UN.COP Seminar participants are asked to evaluate the course through responses to a questionnaire made by the course organizers (Figures 4-6).

5. CONCLUSIONS

An effort is being made to develop a proposal for a systematic approach to user training. The estimated duration of the course venue, including a set of training seminars, workshops, and practical exercises, is approximately two years. In addition, the specification and assignment of tasks to be performed by the participants at their home institutions, with continuous supervision from the training center, have been foreseen. The 3D S.UN.COP seminars training courses constitute the follow-up of the presented proposal. The problem of the code-user effect along with the methodologies for performing the scaling, the BEPU, and the 3D coupled-code calculation analyses are the main topics discussed during the course. It is given emphasis to practical applications in connection with the licensing process of best estimate plus uncertainty methodologies, showing the designer, utility and regulatory approaches. The responses of the participants during the training demonstrated an increase in their capabilities to develop and/or modify the nodalizations and to perform a qualitative and quantitative accuracy evaluation. It is expected that the participants will be able to set up more accurate, reliable, and efficient simulation models applying the procedures for qualifying the thermal-hydraulic system code calculations and for the evaluation of the uncertainty.

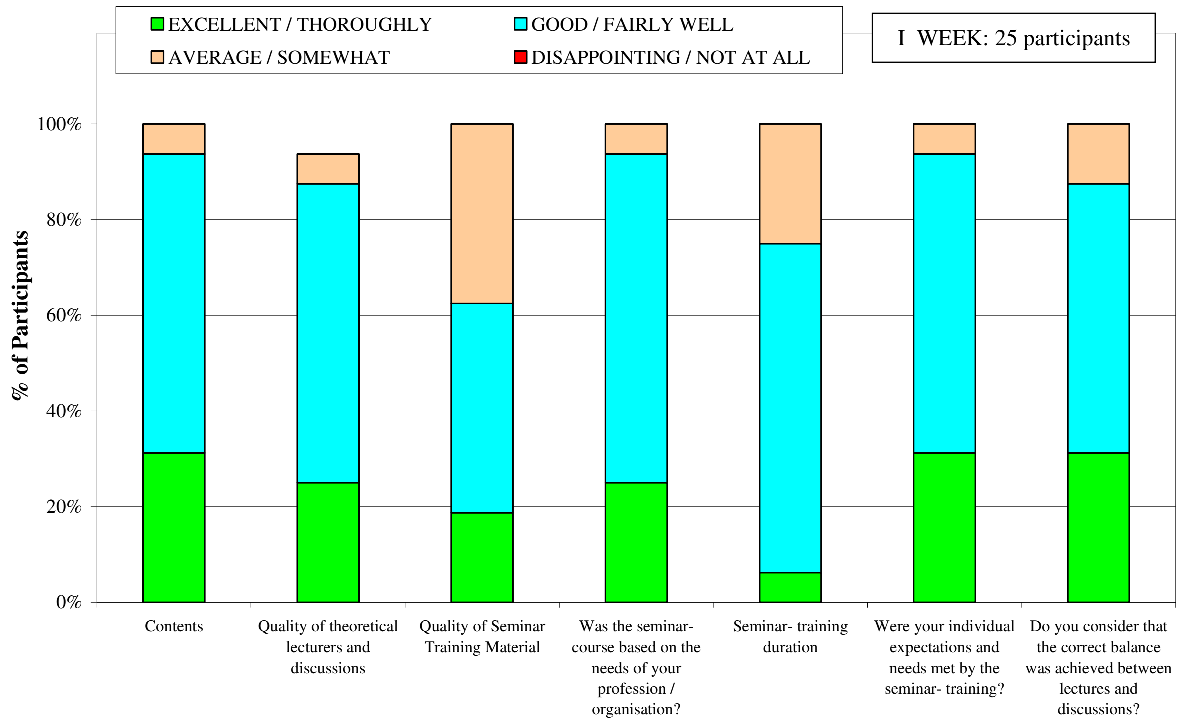

Figure 4: Design and conduct of the seminar training – I Week.

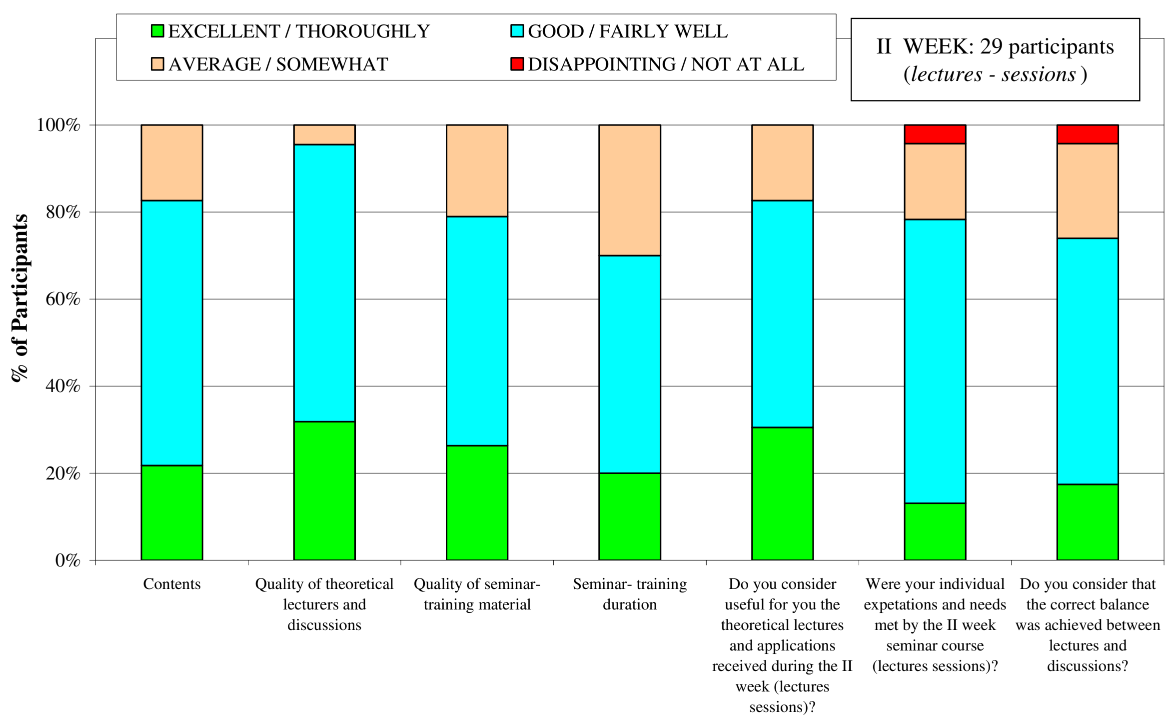

Figure 5: Design and conduct of the seminar training – Lectures II Week.

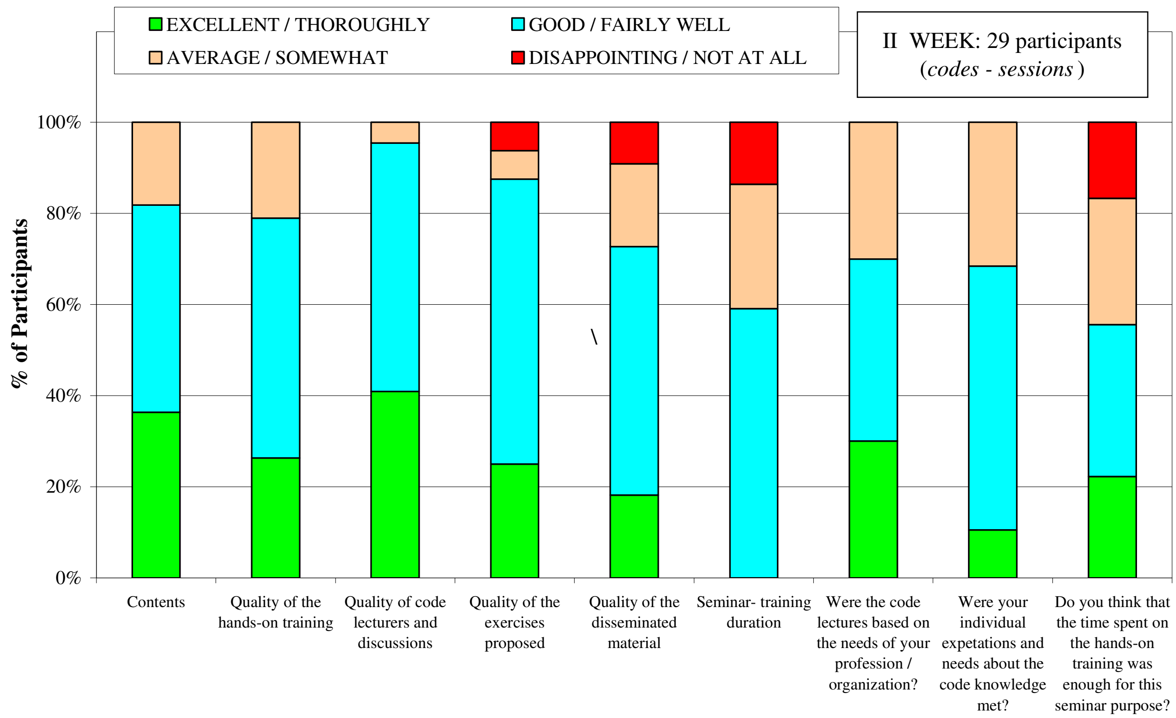

Figure 6: Design and conduct of the seminar training – Codes II Week.

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