Nuclear Technology Master: a New Tool for Supervising and Transfer Knowledge of Nuclear Technology

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ABSTRACT

Current computer systems which are used for accident and transient simulation at nuclear power plants can roughly be divided into two categories. Within the frame of licensing of a NPP, nowadays "Best Estimate" codes are used (the first category). These computer codes should be able to simulate the behavior of the plant as accurate as possible. Calculation time may exceed the time of the simulation up to several orders of magnitude (i.e. calculation of a few seconds of a complex transient may need several days of calculation time).

Application of computer systems for training purposes (the second category) has different characteristics. To provide the capability to train plant operators a full replica of the control room of the NPP is needed. Hardware and software together in this context are called full scope simulator (FSS). A FSS aims to simulate typical operational conditions and transients in real-time. Complex accidents, characterized by multiple failures, low probabilities of the event and severe plant conditions are typically beyond the capabilities of a FSS. Traditionally, FSS deploys computer codes and models optimized for calculation time, but with considerable simplifications.

This paper describes the model design of the NUTEMA, a computer system for nuclear plant analysis and training, currently under development. The targets and novelty of the project with respect to the existing computer systems are highlighted. NUTEMA (Nuclear Power Plant Technology Management System or Nuclear Technology Master) aims at having virtually available in one room whatever is concerned to a nuclear power plant. NUTEMA system assembles all together the competencies needed for the construction, the design, the management of an NPP and allows the training of nuclear industry staff according to the concept of Design Authority introduced by IAEA (International Atomic Energy Agency). NUTEMA prototype is under development by the University of Pisa for the nuclear power plant Atucha II.

1 INTRODUCTION

A nuclear power plant shall be seen as the most complex system produced by the humanity: the single plant is constituted by several hundred thousand components.
Construction tolerances as small as $10^{-4}$ m are linked with components having main dimension as large as $10^2$ m; the water pressure changes in the range from $10^2$ to $10^7$ Pa, within the NPP. Neutron fluxes generate heat and radioactivity inside the boundaries. Thermal power is removed by water producing steam which moves turbines and alternators to produce electricity. It’s really a colossal multi-scale and multi-physics system.

NUTEMA project is justified by the complexity on NPPs and intends to provide the demonstration of the capability to control the nuclear technology. NUTEMA could be defined as “the NPP in one room”: definition as simulator, database, knowledge management, reflect just some of its peculiarities.

The objective of NUTEMA is to create an integrated expert system having comprehensive and detailed knowledge of NPP structures and components, including software and results of software applications, capable of managing the knowledge and the expertise needed for the design, the construction, the operation and maintenance, the fuel life cycle, the licensing and the safety: it is also suitable for training the personnel.

The target for NUTEMA are the utilities which must purpose the objective of being responsible of the NPP at any condition and at any age, under any licensing and any liability framework, including the capability to dialogue with the Regulatory Authority and the Public Authorities.

The purpose of the present paper is just to highlights NUTEMA, its basis and to inform about the potential applications. However an exhaustive picture of NUTEMA features is out of scope of the present paper.

2 GENERAL FEATURES

NUTEMA is an acronym for two definitions, Nuclear Power Plant Technology Management System or Nuclear Technology Master, both giving an idea of its features.

2.1 The Virtual Components

According to picture 1 NUTEMA consists of two main virtual components, a database (called DMS) where any information related to any component part of the specific NPP is stored and the managing system of computational tools (called INPACEA) that are suited for any of the operation modes (see section 2.2) of NUTEMA. Codes, row NPP data (e.g. material data), input decks, various types of additional software (e.g. code coupling, uncertainty estimation or for processing code input and output data) are installed; there will be also procedures to demonstrate the qualification of computational tools including relevant databases.
The NUTEMA idea came from the IAEA “Design Authority” concept and the streamlining guidance was approved by Quality Assurance (in fact both ISO and ASME-NQA certifications are already achieved and in progress to be acquired by NUTEMA designers); the design and the application of NUTEMA are driven in every aspect by QA.

Sample contents of the database and of the code manager could be seen in picture 1 together with the typical expected outcomes from the operation of NUTEMA.

2.2 The Operation Modes

NUTEMA has six independent but interconnected modes of operation.

0. Financing
   The decision to realize a NPP implies a complex process often touching the political strategies of a Country, the predicted financial and technological development and the comparison with other energy sources. The process may typically need years and end-up with a national energy plan.
   - Starting from the idea of an NPP
   - Availability of a solid/documentated financial environment

1. Design
   The design documents for NPP are already available by the vendor – designer at any time when the request for the construction comes from any utility. NUTEMA operation mode “Design” consistently with the Design Authority concept is to gather or to reconstruct the expertise available by the vendor.
   - Siting
   - Large components
   - Architect engineer
   - PSAR (Preliminary Safety Analysis Report)
2. **Construction**

The management of the personnel as well as the selection of staff and the planning of the activities during the construction period of the NPP shall be considered under the current operation mode of NUTEMA

- Civil works
- Mechanical works
- I & C work

3. **Operation and maintenance**

The production of electricity constitutes the main target of the operation in any NPP. Ensuring the highest efficiency of the production is mandatory. This goal is achieved by optimizing the use of nuclear fuel as well as reducing the maintenance periods. The proper staff qualification is necessary.

- Maintenance
- I & C management
- Fuel cycle management from mining to waste

4. **Safety**

- **Licensing**
  - 10 CFR 50
  - FSAR
    - Chapter 15

  - LBLOCA
    - Effect of ECCS
      - Pump suction
      - Valve opening time (effect)
    - Containment performance

- **PSA**

Procedures and supporting computational tools to perform Deterministic Safety Assessment (DSA) and Probabilistic Safety Assessment (PSA) are included in NUTEMA: each one of them is considered within the design, the construction and the operation of NPP. Furthermore, V & V (Verification & Validation) represents a key element to perform and to make acceptable safety studies and national regulation (rules or even national laws) must be fulfilled at any step of a safety analysis. In addition security can be seen as also a complement to safety. All of this is present in NUTEMA.

5. **Decommissioning**

The end of a NPP signifies the decommissioning or better the identification of any destiny for the unit following its operational life. Decommissioning implies a suitable financial plan and a time schedule. The radioactivity of the NPP materials and components makes expensive this particular part of the NPP life cycle, with cost may strongly depend on the time passed after the NPP shut down.

- Ending with the green field restoration
3 THE SUBJECTS OF NUTEMA

Into NUTEMA subjects we shall include everything that is connected with the NPP including any related structural or logic link. Here is reported a short list of NUTEMA subjects.

Siting Characteristics

- Historical data (meteorology, hydrology, seismology, radiology, population)
- Excavation data
- On-line weather

NPP Design Features

- Structural mechanics
- RPV (reactor Pressure Vessel) design features
- Safety of NPP at the design level
- Balance of Plant (BOP)

NPP Operation and Maintenance

- Operational tests specifications, conduct and analysis
- Safety of NPP at the O & M level
- Security measures
- Radioprotection
- Online NPP conditions
- Online control Room
- On line BOP

Fuel Cycle

- Nuclear Physics
- Fuel design
- Fuel procuring
- Waste management
- Determination of CHF (Critical Heat Flux) characteristics

Licensing

- Reliability
- National Authority documents
- PSAR, FSAR and related modifications (including keeping track)
- Requests by Regulatory Authority
- Results from the application of V & V procedures
- Uncertainty methods
Visualization including Simulator-like performance

- Simulator and NPA (Nuclear Plant Analyzer) performance
- Control Room monitoring

Liability & Policy/Strategy

- Strategy for decommissioning
- Insurances
- Public Information

NPP off-nominal conditions

- AOO (Anticipated Operational Occurrence)
- DBA (Design Basis Accident)
- SAMG (Severe Accident Management Guidelines)
- Thermal-Hydraulics
- Any accident
- Accident on-line
- Current meteorology
- Evacuation of the population

4 THE TECHNOLOGICAL CONFIGURATION OF NUTEMA

NUTEMA is installed in approximately sixty square meters room including a meeting area for about ten people; the system has a control room-like configuration (see picture 2) including about fifty screens and a video wall having ten square meter area. The video wall and the screens are visually accessible to a passive user or to an observer of NUTEMA system.

NUTEMA also includes:

- Eight additional small screens supporting the operator
- Six touch screens allowing the interaction between operators and the system
- Ten main computers where computational tools are installed
- Six auxiliary computers to manage the touch screens and the interaction among the main computers
- Auxiliary devoted cooling system for screens and computers
- Instrumentation (namely temperatures) and related visualization to detect the operational conditions of the system

The eight auxiliary screens are used to continuously visualize:

- The computers codes installed on NUTEMA
- The input decks installed on NUTEMA
- The codes manuals
- The input deck description
- The content of each of the main computers and of the auxiliary computers
- The identification and the characterization of the installed databases
- The current operational mode of the NUTEMA including the characterization of the available resources
- The current working load for the operating machines including current occupation of CPU, RAM and so on.

Three operators are needed for NUTEMA management; each has access to two touch screens.

Picture 2 – NUTEMA current configuration

5 NUTEMA END USERS

The main target company for the use of NUTEMA is constituted by:

1. Utilities
2. Vendor / Designers
3. Regulatory Authorities
4. Research & Technical Support Organization

6 CONCLUSIONS

NUTEMA, which means either Nuclear Power Plant Technology Management System or Nuclear Technology Master, is an informatics system which allows the accomplishment of “the Nuclear power plant in one room”.

NUTEMA constitutes the storage of relevant data and training and an educational tool in nuclear technology.

The design, the construction and the operation of the NUTEMA hardware, including the demonstration of functionality and the final feasibility study, have been completed or achieved at the time of writing the present paper. The reference NPP is the Central Nuclear Atucha II under construction in Argentina; it will be planned to start a test session for the NUTEMA prototype according to the Atucha II NPP. A further application for NUTEMA is also as tool for comparison different NPP’s design. The working modality as the database and/or management of computational tools have been proved at the present time, including a few thousands files (data base), a couple of dozen system codes and a few tens of input decks installed. The mode of operation “Safety” is possible, though not including every expected capability.

The exploitation of the planned capabilities of NUTEMA will require an additional effort of around thirty man-years. However in the existing configuration the system can already be used to support the Design Authority constitution including training and qualification for any level staff in the concerned NPP.

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