USE OF PRA IN THE NUCLEAR REGULATORY FIELD IN SOUTH AFRICA

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ABSTRACT

The nuclear regulatory authority in South Africa (since 1988 the Council for Nuclear Safety (CNS)), established in 1973 nuclear safety criteria against which to assess the level of safety of any facility using radioactive material. It is a regulatory requirement in South Africa to develop and maintain a living PRA for each facility and thereby to provide the necessary information to demonstrate compliance against these criteria. All safety submissions to the CNS must include at least a risk statement based on an accepted PRA study.

The function of the CNS is to regulate all activities in South Africa involving the use of radioactive material and posing a significant risk to the public or plant personnel. This includes most aspects of the nuclear fuel cycle and the Koeberg NPS (two 2775 MW(th) PWRs).

A PRA study including source terms for the two Koeberg units was presented by the contractor in 1979. This included the risk due to power and shutdown states and non reactor related accidents involving spent fuel storage, fuel handling and waste treatment related activities. At least 20 PRA studies have been performed for other nuclear facilities in the country.

The CNS maintains an in-house PRA capability to perform independent assessments of licensee submissions, to participate in developments of PRA methodology in the regulatory field, to perform pro-active safety work and to assist in regulatory decision making.

Present ongoing work includes the development of a risk monitor, a risk management system, improvements in PRA codes, models, data collection and analysis, off-site risk assessment methodology and associated regulatory policy.

1. HISTORICAL OVERVIEW

PRA has been part of the nuclear regulatory framework in South Africa since the early seventies. Fundamental safety standards were established against which the safety of all nuclear facilities would be assessed. Equivalent source term limits were derived by the regulatory body using a site specific offsite consequence analysis.

It was a requirement on the licensee to provide a valid plant specific PRA to demonstrate compliance against these limits.

Over the past fifteen years PRA studies including source terms have been developed for virtually all aspects of the nuclear fuel cycle in South Africa including the Koeberg NPS, Safari-1 research reactor, approximately twenty facilities of the Atomic Energy Corporation of SA, waste repositories and more recently, for certain facilities relating to mining operations. These submissions have been used by the regulatory body to assess compliance against the above criteria.

As regards the Koeberg NPS, the source terms provided by the contractor in 1979 included the following:

- Power and shutdown modes
- Spent fuel storage and fuel handling accidents
- Waste treatment related accidents.

Subsequently the PRA has been revised in accordance with developments in this field.

The present fundamental safety standards (Table 1) include risk to the public and plant personnel due to normal operations and accidental releases and include limits on maximum and average individual risk. For societal risk, a bias against larger accidents is imposed (Figure 1).

2. GENERAL REQUIREMENTS

It is a regulatory requirement in South Africa that licensees submit a plant specific PRA, with associated source terms, to the regulatory body for assessment against the risk criteria given in Table 1. This applies to any facility which uses radioactive material and poses a significant risk to the public or plant personnel. Although compliance against these criteria is determined by the regulatory body, guidelines are made available to the licensee as to how this is performed.

The nuclear licence for the facility is drawn up by the regulatory body to ensure regulatory control over important aspects of the facility relevant to the safety case. This includes the plant specific PRA.

A proposed change to any of the above items referenced in the licence, or any modification to the plant which could impact on risk, requires a licence change request to be submitted to the CNS with supporting safety case to demonstrate risk compliance.

In addition to the above, the licensee is required to maintain the validity of the PRA on an ongoing basis by, inter alia, updating the reliability data base, performing root cause analysis on occurrences and ensuring that equipment reliability is in accordance with the PRA data base.

As generic reliability data is used, at least in the early stages of operation for a new plant, it is implicitly assumed that the plant is constructed and operated according to the same standards as those plants from which the data is obtained. The licensing process attempts to ensure that this remains valid via appropriate licensing requirements based on overseas practice. Subsequently, plant specific data, where available, is checked against generic data.

Defence in depth is further provided by the fact that certain basic principles upon which the PRA is based, including the design basis, are reflected in the licence. Deviation from the design basis therefore requires an LCR which has to be motivated by a PRA study.

3. SCOPE OF REGULATORY PRA WORK

3.1 Responsibilities of the Licensee:

The licensee is required to maintain a current, plant specific PRA including:

Reliability data base:
- component reliability data including:
- demand and running failures
- mission times
- common mode data
- human reliability data.

Initiating event study including:
- initiating event screening
- frequency quantification.

System reliability analysis including:
- support systems
- mission times
- failure/repair cycles.

Plant level event sequence quantification including:
- common mode within and across system boundaries
- identification of plant damage states
- system failure criteria.

Source term analysis:
- identification of release categories
- frequencies of release categories (mean values).

Requirements on licensees with regard to the following are under consideration:

- Development and use of a risk management system to

account for actual and scheduled changes in risk,
- Data collection and analysis for component and human reliability data,
- Root cause analysis on occurrences and derivation of failure rate and common cause data, including variances for use in the PRA.

3.2 Responsibilities of the Regulatory Authority:

Establish principals according to which PRA is used in the regulatory field for all installations posing some form of nuclear risk.

Develop fundamental risk criteria by comparison with other societal risks, and based on experience of nuclear facilities world wide.

Establish in-house methodology to check and assess licensee submissions and perform pro-active safety work.

Maintain an in-house PRA capability to participate in development of regulatory PRA methodology and associated requirements.

Assess source terms submitted by the licensee by performing offsite consequence analysis and operator risk analysis.

For this purpose maintain valid site specific databases for use in the above assessments (demographics, meteorology, human mortality data, food chain data etc.).

Establish requirements relating to:

- Development and maintenance of a living, plant specific PRA,
- Plant specific data collection and analysis
- Risk management
- Operational feedback using PRA.

Use PRA to identify regulatory priorities, inspection programmes, auditing requirements etc.

Provide in-house training in PRA to CNS technical staff.

4. REGULATORY APPLICATIONS (KOEBERG NPS)

For the approval of the design and commissioning of the twin 925 MWe PWR units of the Koeberg NPS the utility Eskom provided in 1979 a source term PRA study prepared by the contractor. This study provided iodine equivalent source terms due to reactor accidents from power and shutdown conditions, spent fuel pool, fuel handling and waste treatment related accidents. A seismic risk study was performed.

The resulting source terms were compared with the derived iodine equivalent source term limits discussed in section 1 above.

The plant was initially non compliant against these criteria due to risk exposures relating mainly to concerns relating to offsite power supplies and ultimate heat sink. To address these concerns, the utility provided a dedicated power line to the plant from a power source independent from the national grid, and developed new procedures to utilise additional sources of cooling water in the event of loss of ultimate heat sink.

In 1972 the decision was taken to discontinue use of the iodine equivalent source term limits and to revert to the fundamental safety standards, with the requirement that the licensee provides source terms computed using an acceptable methodology. These source terms are then used to assess overall plant safety and compliance against the risk criteria as discussed in 3.2 above.

In recent years the utility has been required to implement shutdown technical specifications and to carry out various modifications relating to the fast dilution accident and loss of cooling at shutdown.

On the basis of risk, a concern relating to fuel handling in the reactor building has recently been addressed.

More than 700 licence change requests regarding the Koeberg NPS alone have been submitted to the CNS. Each submission includes a safety case based on the approved PRA study or at least a risk statement.

PRA studies have been performed to assess the following:

- Urban development assessments
- Safety issues (new scenarios, changes in source term technology etc.)
- Feedback to emergency planning and accident management
- Identification of safety issues for operator training.

5. PRESENT DEVELOPMENTS

The various nuclear licenses and regulatory guidelines are being rewritten to reflect developments in the risk based approach.

The following PRA code and model developments at system and plant level are either in progress of are under consideration:

- Improved fault tree/event tree code system
- Improved treatment of failure/repair cycles based on Markov approach
- Extension of common cause groups
- System of data collection and analysis

- Risk monitor
- Risk based maintenance rules.

Other developments taking place include the offsite consequence models as regards:

- Meteorological data
- Atmospheric dispersion data and models
- Collection and analysis of demographic data, including the food chain
- Models for mining operations.

In conjunction with the development of a risk monitor, requirements and methodology for the establishment of a risk management system are being developed by the regulatory body and licensee.

Requirements on the performance of root cause analysis on occurrences may be extended to include plant specific data analysis and trending.

6. CONCLUSIONS

i. According to our experience PRA is an essential tool in regulatory decision making, providing a rational, structured approach to the resolution of complex and diverse problems not adequately addressed by other methods.

ii. PRA should be regarded as an extension of traditional (deterministic) thinking to take into account the reliability of the plant as a whole in quantifying risk.

iii. PRA should be used to provide a total picture of plant safety, using plant specific data from diverse sources reflecting the actual condition of the plant.

iv. Commitment to the PRA is necessary to avoid erroneous, misleading results and unnecessary use of resources.

v. Requirements based on the use of PRA in the regulatory field help to ensure commitment to PRA development and to justify the necessary resources.

vi. The existence of large uncertainties in the PRA is not a reason for rejecting the PRA approach in the regulatory field, as these are implicit and common to any decision making process.

vii. International co-operation could assist in reducing the overall resources needed for plant specific PRA development and reviews, establishment of a consistent methodology and development of supporting tools and databases.

NUCLEAR SAFETY STANDARDS

UNITS: FATALITIES/PERSON/ANNUM

	POPULATION	OCCUPATIONAL	
		ACCIDENTS	ACC. + NORMAL OPERATION
INDIVIDUAL	5×10^{-6}	5×10^{-5}	10^{-3}
POPULATION AVERAGE (ALL FACILITIES)	10^{-7}	----	----
POPULATION AVERAGE (PER FACILITY)	10^{-8}	10^{-5}	2×10^{-4}
PEAK TO AVERAGE	50	5	5
BIAS	figure	----	----
ALARA	yes	yes	yes

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Figure 1. Risk aversion criterion and risk curve for nuclear facility