INTEGRATED PLANT LIFE MANAGEMENT (PLIM) – THE IAEA CONTRIBUTION

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ABSTRACT

For the past couple of decades there has been a change of emphasis in the world nuclear power from that of building new Nuclear Power Plants (NPP) to that of taking measures to optimize the life cycle of operational plants. National approaches in many countries showed an increase of interest in Plant Life Management (PLiM), both in terms of plant service life assurance and in optimizing the service or operational life of NPP. A strong convergence of views is emerging from different National approaches, particularly in the area of the economic aspects of NPP operation and in the evolution in the scope of NPP PLiM.

The latter can directly affect the cost of electricity from NPP in an increasingly competitive environment. The safety considerations of a NPP are paramount and those requirements have to be met to obtain and to extend/renew the operating license. To achieve the goal of the long term safe, economic and reliable operation of the plant an integrated Plant Life Management Programme (PLiM) is necessary. Some countries already have advanced PLiM Programmes while others still have none. The PLiM objective is to identify all that factors and requirements for the overall plant life cycle. The optimization of these requirements would allow for the minimum period of the investment return and maximum of the revenue from the sell of the produced electricity.

Recognizing the importance of this issue and in response to the requests of the Member States the IAEA Division of Nuclear Power implements the Sub-programme on "Engineering and Management Support for Competitive Nuclear Power". Four projects within this sub-programme deal with different aspects of the NPP life cycle management with the aim to increase the capabilities of interested Member States in implementing and maintenance of the competitive and sustainable nuclear power.

Although all four projects contain certain issues of PLiM there is one specific project on guidance on engineering and management practices for optimization of NPP service life including decommissioning. This particular project deals with different specific issues of NPP life management including aspects of ageing phenomena and their monitoring, issues of control and instrumentation, maintenance and operation issues, economic evaluation of NPP life cycle management including guidance on its earlier shut down and decommissioning.

KEYWORD:

Plant Life Management (PLiM), Reactor Pressure Vessel, Long Term Operation (LTO), Periodic Safety Review (PSR), International Database on RPV.
1. INTRODUCTION

The International Atomic Energy Agency (IAEA) provides a global focus for nuclear co-operation in many areas. Presently, an area of major interest is the management of nuclear power plant (NPP) life cycle from concept development to decommissioning and disposal, with the primary objective of maximising the return on investment in nuclear facilities through efficient operation of NPPs.

During the last 2 decades the number of IAEA member state (MS) giving high priority to continuing the operation of nuclear power plants, beyond the timeframe originally anticipated, is increasing. This is related to the age of NPPs connected to the grid worldwide; out of a total of 441, 81 have operated for more than 30 years, and 253 for more than 20 years. The initially assumed time of operation was typically 30-40 years.

Of these, about 300 NPPs have been in operation for 15 years or more and these older units with partially or fully amortized capital costs have proven to be the most profitable. Moreover, there are no significant safety or economic reasons not to continue the operation of well-managed NPPs over a longer period and consequently the issues of plant life management and license extension are receiving an increasing emphasis in many countries.

2. PLANT LIFE MANAGEMENT

The Life Cycle consists of planning, design, financial arrangements, construction, commissioning, operation, maintenance and inspection, management of the workforce capability, economic assessments of license extension, decommissioning and waste management. Such an integrated approach requires the consideration of a variety of activities to be undertaken during the plant life management programme (PLiM). PLiM can therefore be defined as the total activities, including technical, financial, economic, administrative - managerial and socio - political aspects that are aimed at the achievement of a long term safe and reliable operation within the optimised life cycle of the plant (Fig. 2).
Achieving a safe and economic long term operation (LTO) is equivalent to providing additional generating capacity. This involves an extension of the operational license to the maximum extent possible while maintaining its safety and competitiveness.

It should be remembered that the purpose of the NPP is to generate and sell electricity economically and its revenues have to support the financing of its entire life cycle.

For PLiM, analysis must show that the plant will continue to operate within its design basis. Therefore, there is a need:

- To have a good knowledge of the current design basis of the plant;
- To have a correct picture of the actual state of the plant;
- To define the analysis needed to support LTO and demonstrate that the plant will still operate within its design basis.

Further, mechanisms providing an effective feedback of operating experience and due consideration of advances in science and technology need to be in place.

### 3. IAEA ACTIVITIES

The IAEA is an independent, intergovernmental, science and technology-based organization, within the United Nations family and serves as global focal point for nuclear co-operation. The three main pillars of its activity are safety, technology and safeguard. According to its mandate, the IAEA assists its Member States in planning for and using nuclear science and technology for peaceful purposes, which includes the generation of electricity. It also develops nuclear safety standards, promotes achievement and maintenance of high levels of safety in all application of nuclear energy. In addition, the IAEA verifies that States comply with their commitments, under the Non-Proliferation Treaty and other agreements, in using the nuclear materials only for peaceful purposes.

In response to the needs of the MS the IAEA is implementing several programmes on engineering and management practices for optimisation of nuclear power plant life management. Majority of these activities is concentrated within the IAEA Division of Nuclear Power under the Sub- Programme A1 “Engineering and Management Support for Competitive Nuclear Power”. Four projects within this sub-programme deal with different aspects of the NPP life cycle management with the aim to increase the capabilities of interested Member States in implementing and maintaining a competitive and sustainable nuclear power programme.
While all the projects under the IAEA sub-programme A1, contain certain issues of PLiM there is one dedicated project on “Integrated NPP life cycle management including decommissioning”, as the focal project on the subject. The project scope includes different categories of IAEA activities for the purposes of information exchange and technology transfer. These include arrangements for technical meetings, development of databases and guidance documents on proven practices, coordinated research projects, technical co-operation projects, direct expert services to Member States, training activities and co-operation with other International organizations.

4. DEVELOPMENT OF PLiM GUIDELINES

The IAEA is developing “Principles and Guidelines on Deriving Effective PLiM” for Light Water Reactor and “Guidelines on PLiM processes and practices for Heavy Water Reactors” to satisfy requirements for safe long supplies of electricity in an economically competitive way. The basic goal of the operating company (and the owners) to operate as long as economically reasonable and possible from safety point of view.

PLiM is a management tool for doing that. PLiM is a system of programmes and procedures to satisfy safety requirements for safe operation and for power production in a competitive way and for time which is rational from technical and economical point of view. PLiM is not only a technical system, it is also an attitude of the operational company to keep the plant in operation as long as possible from safety and business point of view. These guidelines were created using existing international experience from the worldwide nuclear power industry and inputs from experts concerned with license renewal and upgrades, regulatory aspects, safety and economic improvements.

5. PERIODIC SAFETY REVIEW (PSR) REGULATION OF LONG-TERM OPERATION

In many countries the safety performance of the nuclear plants is periodically controlled via the PSR system. The regulatory review and acceptance of the PSR give the right for the licensee to operate the plant for the next PSR cycle (usually 10 years). The regulatory system is not limiting the number of PSR cycles even if the new cycle is going beyond the original design lifetime of the plant. The only condition is to demonstrate the safety of the plant operation for the next PSR cycle with some margins. [1]

The PSR is therefore a regulatory tool for the identification and resolution of the safety issues. In this framework the LTO is achieved by applying the PSR, by identification and resolution of the safety issues as a condition of operation for the new PSR cycle. It is clear that the PSR is not a proper tool to control changes and tendencies with an evolution time shorter than 10 years. It is also not a suitable system in case the licensee needs a technological guarantee for a long-term operation longer than 10 years; in many cases economical considerations suggest an extension of 20 years or more of the design life.

However, it should be noted that the concept of PSR was developed to be part of the normal regulatory or safety monitoring process and not specifically to justify long-term operation of a plant. The PSR was originally used primarily to assess the safety status of the plants designed to early standards. In these cases the PSR gives an overall review of all aspects of plant operation that may be relevant to safety. This review includes subjects as emergency arrangements, organization and administration, procedures, research findings and feedback of experience. All of them are mainly relevant to current operation and not directly related to the justification of the long-term operation.

According to recent practice, the PSR has to focus on the cumulative effects of plant ageing, assessment of plant status and modifications, operating experience, modifications of national safety standards science and technology developments, and site hazard modifications. If the PSR process is
to be used for the justification of continued operation of the plant, then special emphasis should be
given to the assessment of aged status and ageing management of those safety related structures,
systems and components (SSC) that limit the operational time of the plant. It is obvious that these
SSCs are those, which cannot be replaced or reconstructed. A PSR implemented beyond the original
design life may require a deeper safety review, addressing the following:

- Evaluation of the plant safety against current standards
- A new evaluation and/or qualification for items affected by time dependent phenomena
- The ageing management programme which has to be extended over the planned operating life
- A new safety assessment, to show that the as-designed conservatism (not the safety margin!) might be reduced based on the careful plant operation and better understanding of the degradation mechanisms. The overall safety margin should be kept consistent with current safety requirements

In conclusion, a full scope PSR applied for LTO is not different in principle than a PSR applied
during the design life, but the emphasis has to be oriented to the ageing of SSCs limiting the plant
operational time and on the related safety issues.

6. AGEING MANAGEMENT

While early in the 1980s most people believed that routine maintenance programmes were
adequate for dealing with the ageing of nuclear installations, in the 1990s the need for ageing and life
management of NPPs became widely recognized. The IAEA initiated activities to promote
information exchange on safety aspects of NPP ageing in 1985 to increase awareness of the emerging
safety issues relating to physical ageing of plant SSC.

Agency follow-up activities were focused on understanding ageing of SSCs important to safety
and on effective ageing management of these SSCs. To assist Member States in managing NPP ageing
effectively, the Agency has developed a technical document on Safety Aspects of Nuclear Power Plant Ageing [3] and a set of programmatic guidelines, component specific guidelines for major NPP components important to safety and ageing management review guidelines.

The following programmatic guidelines on ageing management provide guidance on generic
ageing management programmes:

- Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing [2]
- Methodology for the Management of Ageing of Nuclear Power Plant Components Important
to Safety [3]
- Equipment Qualification in Operational Nuclear Power Plants [5]
- Proactive Ageing Management [6]

The component specific guidelines on ageing management provide component description and
design basis, potential ageing mechanisms and their significance, operating guidelines to control age
related degradation, inspection and monitoring requirements and technologies and assessment and
maintenance methods. Respective roles of major NPP programmes in the management of ageing and
an approach for integrating them within a systematic components specific ageing management programme are shown using an application of the systematic ageing management process. The following comprehensive technical documents on Assessment and Management of Ageing of Major Nuclear Power Plant Components Important to Safety have been published:

- Steam generators [7]
- Concrete containment buildings [8]
- CANDU pressure tubes [9]
• PWR pressure vessels [10]
• PWR vessel internals [11]
• Metal components of BWR containment [12]
• In-containment I&C Cables Volume I and II [13]
• CANDU reactor assemblies [14]
• PWR primary piping [15]
• BWR Reactor Pressure Vessel [16]
• BWR Reactor Pressure Vessel Internals [17]

Development of these guidance documents is beneficial in itself because it provides opportunities to address important issues of common interest and to learn from each other. However, it is the actual application of guidance that has a more significant impact on nuclear safety. The Agency, therefore, devotes significant effort in assisting Member States in the application of its guidance through training courses and advisory safety review services.

Several years ago the Agency started the work on the International Database on NPP Life Management. This is a multi-module Database (Fig.2) first one of which is called the International Database on Reactor Pressure Vessel Materials (IDRPVM) and was implemented already in 1996 and is being used world wide. Four other modules are also completed and the work on receiving the data and filling it into the databases is under way.

One of the important parts of the Integrated NPP Life Management Programme is the issue of maintenance and in-service inspections as the tools for the optimisation of the operational or service life of the plant.

7. REACTOR PRESSURE VESSEL INTEGRITY

Since 1975, IAEA implemented seven CRPs to develop the methodology to evaluate the irradiation effects of RPV with more than 100 organizations and institutes. Based on seven CRPs results, IAEA developed the master curve approach. Agency is starting new two CRPs to verify RPV integrity precisely as follows:

7.1. Irradiation Embrittlement of Reactor Pressure Vessel Steels (Phase 1)

The first project (or Phase 1), "Irradiation Embrittlement of Reactor Pressure Vessel Steels," focused on standardization of methods for measuring embrittlement in terms of both mechanical properties and the neutron irradiation environment. Little attention was given at that time (early 1970s)
to the direct measurement of irradiated fracture toughness of small surveillance type specimens since elastic-plastic fracture mechanics was in its infancy. The main results from Phase 1, including all reports from participated organizations, were published in 1975 in Report IAEA-176 [18].

7.2. Analysis of the Behavior of Advanced Reactor Pressure Vessel Steels under Neutron Irradiation (Phase 2)

The second phase, “Analysis of the Behavior of Advanced Reactor Pressure Vessel Steels under Neutron Irradiation,” involved testing and evaluation by various countries of so-called advanced RPV steels that had reduced residual compositional elements (copper and phosphorus). Irradiations were conducted to fluence levels beyond expected end-of-life, and the results of Phase 1 were used to guide the overall approach taken during Phase 2. In addition to transition temperature testing using Charpy V-notch test specimens, some emphasis was placed on using tensile and early-design fracture toughness test specimens applying elastic-plastic fracture mechanics methods. All results together with their analyses and raw data were summarized in IAEA Technical Report Series No. 265 [19].

7.3. Optimising Reactor Pressure Vessel Surveillance Programmes and Their Analyses (Phase 3)

The third phase included the direct measurement of fracture toughness using irradiated surveillance specimens. “Optimising Reactor Pressure Vessel Surveillance Programmes and Their Analyses” was the title for Phase 3, and significant accomplishments were achieved concerning fracture toughness testing and structural integrity methods, correlations between various toughness and strength measures for irradiated materials, emphasis on the need to understand embrittlement mechanisms, and potential mitigative measures for radiation embrittlement. One key achievement was the acquisition and testing of a series of RPV steels designed and selected for radiation embrittlement research. One of these materials was given by the code JRQ, and it has been shown to be an excellent correlation monitor (or standard reference) material as documented in IAEA TECDOC-1230 [20].

7.4. Assuring Structural Integrity of Reactor Pressure Vessels (Phase 4)

The main emphasis during the fourth phase, which began in 1995, was the experimental verification of the Master Curve approach for surveillance size specimens. This CRP was titled "Assuring Structural Integrity of Reactor Pressure Vessels," and was directed at confirmation of the measurement and interpretation of fracture toughness using the Master Curve method with structural integrity assessment of irradiated RPVs as the ultimate goal. The final report [21] will include a CD with the results of the Phase 3 project. The main conclusions from the Phase 4 CRP are that the Master Curve approach has demonstrated that small size specimens, such as precracked Charpy, can be used to determine valid values of fracture toughness in the transition temperature region.

7.5. Surveillance Programme Results Application to Reactor Pressure Vessel Integrity Assessment (Phase 5)

The Phase five is titled, “Surveillance Programme Results Application to Reactor Pressure Vessel Integrity Assessment.” This CRP has two main objectives:

- Develop a large database of fracture toughness data using the Master Curve methodology for both precracked Charpy size and one-inch thick (25.4 mm) compact tension (1T-CT) specimens to assess possible specimen bias effects and any effects of the range of temperatures used to determine To, either using the single temperature or multi-temperature assessment methods.
- Develop international guidelines for measuring and applying Master Curve fracture toughness results for RPV integrity assessment.
Preliminary results show clear evidence that lower values of unirradiated To are obtained using precracked Charpy specimens as compared to results from 1T-CT specimens. This bias in test results is very important when considering use of precracked Charpy specimens in evaluating RPV integrity.

7.6. Effects of Nickel on Irradiation Embrittlement of LWR RPV Steels (Phase 6)

The Phase six, Effects of Nickel on Irradiation Embrittlement of Light Water Reactor Pressure Vessel (RPV) Steels has been done in 2005 and the objective of the sixth CRPs is to determine the influence of the mechanism and quantify the influence of nickel content on the deterioration of irradiation embrittlement of reactor pressure vessel steels of the Ni-Cr-Mo-V or Mn-Ni-Cr-Mo types. The scientific scope of the programme includes procurement of materials, determination of mechanical properties, irradiation and testing of specimens in power and/or test reactors, and microstructural characterization.

The results analysed are clear in showing the significantly higher radiation sensitivity of high nickel weld metal (1.7 wt%) compared with the lower nickel base metal (1.2 wt%). These results are supported by other similar results in the literature for both WWER-1000 RPV materials, pressurized water reactor (PWR) type materials, and model alloys.

Regardless of the increased sensitivity of WWER-1000 high nickel weld metal (1.7 wt%), the transition temperature shift for the WWER-1000 RPV design fluence is still below the curve predicted by the Russian Guide.

7.7. Evaluation of Radiation Damage of WWER RPVs using Database (Phase 7)

The Phase 7 is entitled “Evaluation of Radiation Damage of WWER Reactor Pressure Vessels (RPV) using Database” to develop guidelines for prediction for radiation damage to WWER-440 PRVs. The WWER-440 RPV was designed by OKB Gidropress, Russia Federation, the general designer. Prediction of irradiation embrittlement of RPV materials is usually done in accordance with relevant codes and standards that are based on the large amounts of information from surveillance and research programmes. The existing Russian code (standard for strength calculations of components and piping in NPPs – PNAE G 7-002-86) for the WWER RPV irradiation embrittlement assessment was approved more than twenty years ago and based mostly on the experimental data obtained in research reactors with accelerated irradiation. Nevertheless, it is still in use and generally consistent with new data.

Using IAEA International Database on RPV Materials (IDRPVM), the guideline is developed for assessment of irradiation embrittlement of RPV ferritic materials as a result of degradation during operation. Two approaches, i.e. transition temperatures based on Charpy impact notch toughness, as well as based on static fracture toughness tests, are used in RPV integrity evaluation.

7.8. Master Curve approach to monitor the fracture toughness of RPVs in NPPs (Phase 8)

The phase 8, Master curve approach to monitor the fracture toughness of RPVs in nuclear power plants is processing during three years from 2005. The determination of neutron radiation embrittlement changes in fracture toughness of reactor pressure vessel (RPV) materials is a key ingredient for integrity assessments to assure current and continued safe operation of Nuclear Power Plants (NPPs). As result of the previous coordinated research programs, “Surveillance Programme Results Application to Reactor Pressure Vessel Integrity Assessment” CRP -5, the technical report series “Guidelines for Application of the Master Curve Approach to Reactor Pressure Vessel Integrity” is in review for publication. Through CRP 5 results, some technical issues are identified to require further study before the Master Curve can be used for realistic RPV integrity assessments, otherwise conservative assumptions must be made.
7.9. Review and Benchmark of Calculation Methods for structural integrity assessment of reactor pressure vessels during pressurized thermal shocks (Phase 9)

The phase 9, Review and benchmark of calculation methods for structural integrity assessment of reactor pressure vessels during pressurized thermal shocks is processing during 3 years from 2005. The overall objective of the ninth CRP is to perform benchmark deterministic calculations of a typical PTS regime with the aim to compare effects of individual parameters on final RPV integrity assessment during PTS, and then to recommend the best practice for their implementation in PTS procedures. This will substantially contribute to better technical support of NPP operation safety and life management. Such deterministic calculations will have broader application in that probabilistic evaluations of RPV failure frequency can utilize these calculations as part of the fracture mechanics sub-routine.

8. DESIGN BASIS DOCUMENTATION

The design basis for SSCs is the information that identifies the specific functions to be performed and the controlling design parameters and specific values or ranges of values for these parameters. The design bases stipulate the function of the SSCs, essential SSC parameters of the stated functions and processes, the basic safety margins to be included in the design, accident and fault scenario expectations, environmental considerations and applicability of safety and industry codes and standards. The design basis of NPPs are used by the plant staff and the regulatory authority in judging the acceptability of the original design and of modifications to the NPP with respect to the safety of the NPP’s personnel, public and environment.

As a pilot project, the Agency has drafted a “Guideline for Design Basis Documents (DBD) Collation and Maintenance for WWER Reactors” [22] and is providing assistance in this area through training and the exchange of experience. In the next step, this Guideline will be generalized to be applicable to all reactor types.

To initiate efforts to consolidate the design basis documentation is particularly important for LTO of older plants. Older plants may require a number of modifications to meet current safety requirements, for which the likelihood that the original designer/vendor may not be able to provide the needed support is highest, and, which for technical, organizational or other reasons do not have this information available.

9. MAINTENANCE PROGRAMMES AND IN-SERVICE INSPECTION

Assurance on a long-term basis of both functional and structural integrity and reliability of nuclear power plant components is a basic condition for any plant life management activity. Component reliability is undoubtedly necessary to maintain plant safety but also to help guarantee the plant availability. Functional integrity of the active components is possible to be maintained by the plant maintenance programme, and in the context of structural integrity and reliability of passive components (pressure vessels and piping), in-service inspection (ISI) and on line and/or periodic condition monitoring are the basic mechanisms to provide information concerning both the presence and size of flaws as well as revealing other deviations from component operating regimes that could threaten their structural integrity. Consequently, maintenance and in-service inspection are fundamental elements of plant life management and their effectiveness strongly influences the production and safety performance of the plants.
A technical document entitled Optimisation of NPP maintenance programmes is under preparation as a part of this activity. The goal of this work is to identify approaches and methodologies in Member States on how maintenance programme optimisation contributes to NPP performance improvement and entire life management. It is recommended to see the process of maintenance optimisation as a continuing process, which is driven by the imbalance between maintenance requirements (legislative, economic, technical) and resources used (people, spare parts, consumable materials, equipment, facilities, collective doses). The process includes details as to how selection of maintenance techniques is achieved to enable the most appropriate type of maintenance is performed on systems, structures and components and at what periodicity to achieve regulatory requirements, maintenance targets concerning safety, reliability and plant availability and cost. This approach can be used also in establishing a preventive maintenance programme.

The initial step of the process provides the benchmark for the maintenance indicators that will be used to recalculate the benefit of the optimisation. Various maintenance optimisation techniques and tools are available and applied to the various extents in the Member States. The process seeks to make the best use of Condition Based Maintenance where unnecessary costly maintenance actions and associated maintenance error induced failures can be avoided. Reliability Centred Maintenance, a methodology aiming at identifying the critical components based on the safety and operational consequences of their failures, plays an important role as well. If a probabilistic risk assessment has been performed, its results can be used to help define the important systems and components.

Preparation of another technical document about Good practices on ISI effectiveness improvement is in progress. Results of round-robin tests within various international research projects as well as the appearance of real in-service defects in pressurized components (e.g. cracks caused by stress corrosion or thermal fatigue) have demonstrated the need for improving ISI effectiveness. There are two ways to be pursued, which should be integrated to strengthen each other’s potential.

The IAEA published a guideline for qualification of ISI systems for WWERs titled: Improvement of ISI for NPP (TECDOC-1400) [23] under one of the IAEA projects Integrated NPP life cycle management including decommissioning.

10. OPERATIONAL ISSUES

An important role in the PLiM integrated approach and namely in the optimisation of the operating or service life plays the issue of the outage management. Outage management is a complex task, which involves in respect of the plant policy, the co-ordination of available resources, safety, regulatory and technical requirements and, all activities and work before and during the outage.

Although, most of the main components of a NPP are designed for plant lifetime operation, some other equipment might need to be updated or exchanged in a plant operating for as long as 40 or 60 years. Refurbishment programs are being planned as long-term activities and in accordance with cost benefit analyses and their importance to safety and availability. It is a key factor for outage optimization to coordinate refurbishment programme and long term outage planning.

Improving the overall economics of a nuclear power plant requires a comprehensive understanding of the relationship between O&M costs and the performance of the plant. It should be recognized that there is a real cost associated with poor performance (lost opportunity for receiving revenues, higher then necessary cost to generate, etc.) as well as the corrective maintenance cost associated with repairing equipment. In addition, there is a mutual interaction between O&M spending and the performance of the plant. Too little pro-active (preventive) O&M spending results in a high frequency of unplanned breakdowns with high corrective maintenance cost and high cost associated with unavailability. The practice of too much O&M spending can put the plant behind the point of diminishing returns. The goal, therefore, is not to minimize O&M cost or to maximize performance (availability, etc.) but rather to minimize the total cost by optimising the O&M cost.
In this context, the Agency has implemented a number of activities directed to outage management and strategy and outage optimisation. The Agency has also developed and implemented in cooperation with the Nuclear Committee of Electric Utility Cost Group (EUCG), the Nuclear Economic Performance Information System (NEPIS) to directly support this optimisation process by providing insight into each of the three steps listed above. In this first phase of its development NEPIS focused on operating and maintenance costs (O&M).

11. CONTROL AND INSTRUMENTATION

There are many reasons why I&C systems need to be modernized in NPPs, including obsolescence, results of aging technology, failure rates, and the need for additional functionality and improved performance. For many plants, I&C modernization will be one of the largest and most important activities over the next decade or longer. Modernization of I&C systems will represent a major capital investment for the plants in the future. Therefore, good and informed management to determine what needs to be modernized, how it should be modernized, and then to do the actual modernization is essential in order to minimize the costs and maximize the benefits. While many reports have discussed I&C modernization topics, one topic that needs more work is how to manage I&C modernization projects efficiently.

In order to have an efficient modernization program, it is essential that the plant does strategic planning to determine what needs to be done with I&C systems in the context of the overall plant goals, objectives, and commitments. This includes determining what the overall I&C, and control room, of the plant should look like at the end of the time period considered by the strategic planning effort, what systems need to be modernized, what systems can be maintained, the priority order of the systems to be modernized, how the systems should be modernized, and so on. To ensure that the individual I&C and control room modernization projects are done consistently with the strategic plan and the overall plant goals, objectives, and commitments, it is important that management establishes a set of plant-specific guidelines and generic requirements and processes that the project will need to follow and that can be used as part of the requirements specifications for the new systems.

High level management leadership and support is needed for I&C modernization in order to maintain the high level, plant-wide perspective needed to initiate and foster the development of these strategic plans, plant-specific guidelines and generic requirements and processes, and to ensure that individual I&C modernization projects conform to them. High level management is also essential for providing adequate resources for successful projects in terms of both people and finances. High level management attention is also necessary to define and assure proper interactions between the plant and regulators and suppliers. This attention is also essential to make sure that all stakeholders for a given project have input into the project.

12. PRESERVATION OF KNOWLEDGE

Management of the NPPs long-term safe and efficient operation requires that their personnel possess and maintain the requisite knowledge, skills, and abilities, to do their jobs. This includes managers, operators, technicians, electrical and mechanical maintenance staff, instrumentation and control technicians, health physicists, chemists, engineers, supervisors, scientists, and supervisors and others depending on the individual NPP organization.

The nuclear power industry in Member States has invested, and continues to invest considerable resources in implementing Systematic Approach to Training (SAT) and SAT-based training programmes, consistent with guidance provided by the Agency in its published Guidebook TRS-80 “Nuclear Power Plant Personnel Training and its Evaluation”.
On the basis of experience gained worldwide in the SAT application, SAT-based training represents now a broad integrated approach emphasizing not only technical knowledge and skills but also human factor related knowledge, skills and attitudes.

The increased control and accountability features of the SAT process provide management and the regulator with the means of applying standard QA procedures and processes at any stage of the training process. The requirement for the training process to conform with the plant QA programme provides management and the regulator with far greater confidence in the qualifications and competence of personnel than that provided by a purely examination-driven assessment. SAT is a QA approach to training and therefore plays a significant role in the overall nuclear power plant QA programme.

SAT based training eliminates or minimizes the competency gaps that affect nuclear power plant safety and efficient operation. A SAT based training system provides continuously inputs for other processes to enhance NPP safety and reliability, such as the upgrading of plant procedures, systems and organizational structure, as well as human resources management during the whole Life Cycle of the plant.

13. ECONOMICS OF PLANT LIFE CYCLE OPTIMIZATION

An operating NPP needs to pay for the construction and design costs, in addition to operating costs, from the revenue received. In addition it needs to ensure that adequate funds are generated and retained to cover future decommissioning and waste liabilities that will need to be paid when the plant is no longer generating revenue.

Generally plants are designed to achieve an identified operating life, and the capital costs are paid from revenues received during this identified period. If the plant is able to operate beyond this identified period then there are no costs associated with the initial capital investment and hence the plant is able to operate with much greater potential profit margins.

The decision to permit the extension of a license for an NPP is quite complex. It may involve a number of political, technical and financial issues, and may require significant investment to justify the license extension. To address Member States needs on the economic aspects of license extension/operational or service life optimization the Agency embarked in a number of activities aimed to gather worldwide existing experience to assist utilities in Member States. Some of them are given below.

A technical document on Cost drivers for the assessment of NPP life extension (TECDOC-1309) [24] has recently been published. The objective of this technical document is:

- To provide an understanding of the various cost elements and drivers in NPP life management.
- To present cost data collected through a questionnaire sent to IAEA Member States and to discuss and identify the basis of the available cost estimates of different activities. This will allow users to draw their own conclusions for input into the economic assessment.

The Agency is also involved in the development of some practical tools in the economic assessments. One of them is The computer model for economic assessment of NPP Plant License extension. The objective of this activity is to develop a PC based computer model to assist plant owners in Member States with the assessment of economic effectiveness of extension and other generation options including consideration of deregulated/privatised electricity markets. What level of nuclear performance will be required to become and remain competitive; what will the market price of electricity and other energy products be; what will be a sufficient return on investment and at what level of risk; what's the value of a NPP at auction; how much can one bid and still make a profit; and what generation alternatives should be considered.
The ongoing activities and the objective and the scope of the package were agreed and a detailed plan of further actions was prepared. The plan received the name FINPLAN and is intended for the use in the development of the above mentioned computer model.

14. CONCLUSIONS

For the past decade the IAEA has continued to be the focal point on information exchange and technology transfer for plant life cycle management programmes and related activities. The following conclusions concerning PLiM in NPPs may be drawn.

PLiM requires full and concise, accurate documentation on all SSCs, including materials, treatments, manufacturers, modifications. Comprehensive documentation allows operators and regulators to follow the progress of ageing (and the effectiveness of any mitigating actions) in NPPs. For effectiveness, PLiM necessitates sufficient, well-trained NPP personnel, which have a questioning and interactive attitude.

Since there are clear benefits to be gained in terms of both safety and economics, as well as assuring supplies of power, PLiM is recognized as an essential part of NPP operation. Utilities or operators contemplating PLiM with a view to continuing NPP operating life past the nominal design life will have to demonstrate to regulators that the SSCs and also human resources are adequate. A correctly conceived and implemented PLiM programme will be a pivotal discussion point and a decisive argument to use, as far as the technological aspects are concerned. Transparent, logical and state of the science PLiM practices may also find application in political arguments for cases where NPP operation exceeding the nominal design life of a NPP is being proposed.

PLiM should be an integral part of the NPP’s overall maintenance, replacement, monitoring and regular servicing schedules, whereby it is recognized that PLiM focuses mostly on large, passive components that cannot be replaced (RPV, containment) or are economically prohibitive to do so. All other components are deemed to be technically and economically replaceable, should safety and reliability issues arise.

In a wider sense of the term PLiM, it is recognized that if NPPs operate in excess of their nominal design lives, then provision should also be made for extra storage capacity of spent fuel and other associated radioactive waste. The “current licensing basis” approach, with the condition that all safety and legal requirements at the time of issuance are satisfied, or are even exceeded, will facilitate operation in excess of the nominal design life.

The PSR will remain an important tool to assess the safety of NPPs. PLiM plays a key role in assuring that safety and design margins are kept. The outcome of the PSRs dictates whether a NPP will be allowed to operate further, or not.

The technical part of the LTO programme should be coupled with a regulatory review process. The IAEA recommends the use of PSR for such purpose, but other approaches could also be appropriate and acceptable. The preconditions, for example, are probably shared among many plants in Eastern European countries in terms of need for: the design basis reconstruction, the updates of the FSAR, and the recovery of the equipment qualification status.

REFERENCES


16 International Atomic Energy Agency, BWR Reactor Pressure Vessel, TECDOC, IAEA, Vienna, in press.


