Nuclear power plant performance: Sustaining initiatives for progress

The performance of nuclear plants has been steadily improving and countries are taking initiatives to ensure continuing progress

by Boris Gueorguiev and K. V. Mahadeva Rao

Nuclear power is a mature part of the energy mix in many countries today. To reinforce its role, national nuclear authorities are placing greater emphasis on improving all aspects of plant performance. Better plant performance will not only yield more efficient production of electricity, but will also generate more confidence in the safety, economic competitiveness, and environmental advantages of nuclear power plants.

One basic indicator of the technical and economic performance of an electricity plant is known as the energy availability factor (EAF). It is the ratio of a plant's net energy generation in a given period, expressed as a percentage of the maximum energy that could have been produced had the plant been operating continuously during that period. Based on data reported to the IAEA's Power Reactor Information System (PRIS), there has been a steady improvement in the EAF for the world's nuclear plants over the past decade. It rose to 76.8% in 1995, up from 70.1% in 1989. *(See graph on page 10).*

Another measure of performance is related to what are called energy losses. The extent to which these can be minimized is an indicator of how well the plant is performing. Energy losses can be either planned (i.e. controlled by management) or unplanned, and they generally are related to outages for refuelling, maintenance, or testing, for example. Over the past three years worldwide, energy losses have been declining at nuclear plants. This is an indication of continuing improvement in the plant's maintenance and management.

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Overall, these performance and management improvements largely can be attributed to the process of utilities learning from experience. At the same time, however, various initiatives taken by countries, frequently working through technical programmes of the IAEA, have played a significant role.

National initiatives for improved performance and safety

The focus of many initiatives in the Agency's Member States has been on improvements in operation, maintenance, and management of nuclear power plants. Such improvements also lead to higher levels of safety at these plants. The initiatives may be divided into five areas, as described below:

Increasing production. This includes taking steps to maintain good plant material conditions through the establishment of high expectations and an attitude of zero tolerance towards defects that can be corrected immediately; reducing the duration of planned outages through more effective planning; performing on-line maintenance, where appropriate, to reduce the duration and cost of planned outages; and reducing the frequency of forced outages through measures such as long-range modification/improvement programmes, the use of modern monitoring equipment, training of plant personnel, and feedback of experience from other similar units.

Reducing workload. This includes taking steps to avoid unnecessary regulatory burdens by modifying or deleting redundant requirements; monitoring the condition of plant equipment as a basis for optimizing preventive maintenance; using maintenance monitoring and analysis techniques that identify requirements

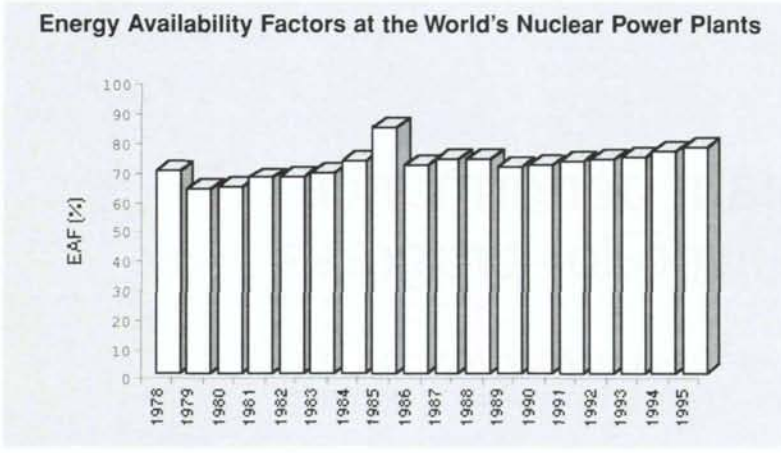

Photo: **Nuclear plants provide about 17% of all the world's electricity. (Credit: Gundremmingen, Germany)**

for equipment according to the safety and operational consequences of failures and the degradation mechanism responsible for them.

Improving work processes. This covers better planning and scheduling over the short, medium and long ranges; using computerized information management systems to support work planning, and maintenance of data on equipment history, cost controls and accounting, including the management of spare parts; applying graduated work controls to provide a means of tailoring the work control process to the significance and complexity of each activity; and post-maintenance testing to check performance of equipment and systems for compliance with design intent.

Improving productivity. This covers human performance through measures such as improving the competence of personnel, tailoring work processes to facilitate staff performance and effective leadership; building better teamwork through the use of multi-disciplinary groups in an organizational structure specifically designed to reduce interfaces and increase job satisfaction and employee morale; sharing of various human resources between different units and sites; sharing of data and experience; sharing of expensive equipment and spare part inventories; and sharing training programmes and facilities; outsourcing/contracting of support services required for maintenance and operation of facilities excluding the main operating and maintenance tasks of a utility; improving management to reduce occupational radiation doses to personnel, minimize contamination, and minimize the volume of radioactive waste arising from maintenance activities.

Measuring performance. This includes establishing performance measures that are objective, observable, measurable and related to results rather than efforts; the use of benchmarking procedures including comparing work performance with that of the best utility, identifying best practices, and implementing a programme to continuously improve performance.

It should be noted that these areas do not explicitly address plant safety and quality assurance, which have justifiably received considerable attention at nuclear utilities. It is recognized that safety and quality are fundamental requirements for the successful utilization of nuclear power and are an inseparable part of each and every activity performed by nuclear power plant personnel. Experience has shown that efforts to improve the efficiency and effectiveness of nuclear plant operation and maintenance programmes, and enhancing the quality of their implementation, have also led to improvements in safety and reliability of plant systems.

Focus of IAEA activities

At the international level, the IAEA has been closely involved in a number of key areas related to the improvement of nuclear plant operations. They include the following types of activities:

Establishment of effective quality assurance programmes. An essential tool for achieving a sustained improvement in plant performance is the establishment of an effective quality assurance (QA) programme. The Agency has updated its safety standards to reflect the modern concept of performance-based QA. The work was done over a five-year period in co-operation with Member States and specifically resulted in the revised Nuclear Safety Standards Quality Assurance Code and its fourteen associated Safety Guides.

During the revision process, the IAEA drew upon the latest experience and considerable

resources in countries and at three organizations, namely the European Commission, European Atomic Forum, and the International Standards Organisation. All documents were critically reviewed by the IAEA's Member States before their approval in March 1996.

Management of the procurement activities in a nuclear installation. Managing the services and supplies of contractors requires effective controls to ensure quality and safety. Experience has shown that difficulties can otherwise arise. The topic has been discussed within the framework of IAEA regional technical co-operation projects in Latin America, Asia and the Pacific, and Eastern Europe, and has been pointed out in a number of missions carried out under the IAEA's Operational Safety Review Team (OSART) programme.

In response to needs, the Agency has developed guidance on management practices for controlling quality and safety aspects when employing suppliers/contractors. It also has issued a technical document on the subject for senior managers, line managers, and line supervisors in a nuclear installation.

Plant life management. As plant equipment and major systems grow older, the life management and life extension of a nuclear plant are becoming increasingly important areas of interest. IAEA activities are directed at facilitating the exchange of information and experience for understanding and monitoring the ageing mechanisms affecting the main systems and components, and at providing technical guidance.

An extensive co-ordinated research project on the life management of the reactor pressure vessel primary nozzle was completed in 1996. The work included a review of the ageing process, methods for monitoring the process, measures to mitigate its consequences, and identification of gaps in knowledge. Results of studies enabled identification of different factors affecting the performance of the components. Work now has started on the development of an international database on nuclear power plant life management and major plant components. The first part covers reactor pressure vessel materials, and the first set of data includes about 1500 items on the material properties of such vessels.

Management of the utility-regulatory interface. Managing the interface between the utility and the regulatory body can present difficulties, and improvements are required in many cases. No specific guidance has been available. Because the topic is relevant to plant safety, the IAEA convened an advisory group of experts drawn from nuclear utility managers and regulatory body officials. The group identified a generic set of difficulties, as well as good practices and opportunities for improvement. The good practices relate to the independence of the regulatory body; clarity on the role and functions of the regulatory body; use of a non-prescriptive regulatory approach; well-defined communication procedures; frequent utility-regulator meetings; joint activities in areas such as training and the review of research and development results; and establishment of standards for provision of regulatory services.

Quality assurance in the management of regulatory functions. The application of formal QA requirements to regulatory functions is a sensitive area that needs to be addressed for improving nuclear plant performance. It is receiving progressive attention and was the subject of a meeting of specialists organized by the Agency in 1996.

The main conclusions include the following: Typical difficulties experienced in the discharge of regulatory functions (such as a lack of procedures and standards for the work, unavailability of a system for documentation, and poor communication practices) indicate the need for applying a QA programme. A number of constraints in the application of QA to regulatory functions were identified. They include normal resistance to change; requirements for additional resources (human and financial) for introduction of QA; and a faulty perception that systematic functioning would restrict creativity, judgement, and efficiency. Specialists at the meeting further agreed on the need to develop specific guidance on the subject.

Technical support to operations. A key factor in improving nuclear plant performance is the quality and organization of technical support (TS) services to the operating organization. As guidance on the subject, the IAEA has prepared a technical document presenting good practices in a number of countries. The core functions of TS are to periodically review plant procedures for consistency with management directives, permanent modifications, and changed plant conditions. Reviews should include verification and validation of new or changed procedures as well as records and information systems. TS further should serve as an effective programme to detect deficiencies, determine their root causes, and identify corrective actions to prevent recurrence. It should also be involved in the preparation of

licensing documentation, including revisions arising out of modifications.

Apart from day-to-day involvement, TS staff should address long-term issues. These are related to the optimization of plant operations; feedback of operating experience to enable learning from events that happened at the plant and at similar plants elsewhere; monitoring of equipment qualification programmes; and overseeing the plant life extension programme.

Computer and related systems. In the past decade, there has been a growing need to address obsolescence of control and instrumentation systems, improve human performance, and to comply with increasingly stringent regulatory requirements. As a result, nuclear power plants have replaced ageing analogue systems with digital systems and have introduced comprehensive and accessible information database and management systems. These systems support operations and maintenance to achieve an overall improvement in quality assurance and productivity. The advances in information and communication technology have helped utilities operate power plants more efficiently by integrating computer resources and increasing the availability of information to meet the needs of plant staff and corporate business strategy. In response to the current needs for modernization of control and instrumentation, the Agency launched, in 1996, a project aimed at a comprehensive review of modernization issues.

Major goals of using computers in operation and maintenance of nuclear power plants are to improve safety and reduce the risk to capital investment; to reduce the cost of operations and maintenance; to enhance power production; and to increase productivity of employees. Computers provide a number of advantages. They include the ease of introducing complex protective and interlock functions; automatic control of plant conditions that could not otherwise be easily controlled; complex and rapid calculation facilities to allow on-line assessment of reactor conditions leading to improved safety and economy; and availability of video units to display plant conditions, which can reduce control panel size and increase operational effectiveness.

To assist control-room operators, a number of computerized support systems are being used. Examples are displays that graphically show critical parameters or operational data for monitoring. In the maintenance area, computerized support systems have been developed to reduce equipment failures. They allow faster fault detection and diagnosis, and provide the capability to improve planned maintenance of equipment. Other types of systems have been developed to help plan refuelling and to analyze the root causes of events, for example.

In 1995, the IAEA set up a worldwide database on computerized support systems. The first version of a database on operator support systems also was completed in 1996 and distributed to nuclear power plants, design organizations, and other interested national institutions.

Future directions and challenges

Even stronger initiatives at the global level are needed in support of nuclear power development and improved plant performance. Over the near term, the IAEA is planning to emphasize issues of importance to decisions on the role of nuclear energy in national energy plans. Activities will involve national authorities and efforts to enhance regional cooperation to effectively utilize existing expertise and resources.

A central focus will be to support the continuing improvement of the operating performance and reliability of nuclear power plants. This will involve further enhancements of management practices and greater sharing of operating experience and information worldwide. For its part, the IAEA is working to expand its databases related to power reactor operations and plant life management.

Through a co-ordinated research programme, the Agency will also focus on efforts to assure the structural integrity of reactor pressure vessels. This will involve the development of a uniform procedure for testing small specimens to obtain data for analyzing the potential for fractures. Other activities will be directed at the training of nuclear power plant personnel, in light of technology advances and the restructuring and reorganization associated with privatization and downsizing.

Over the past years, the IAEA and nuclear utilities in its Member States have taken a number of positive steps for improving the performance of nuclear power plants, with good results. A major challenge in years ahead will be to ensure that improvements are sustained, and that new initiatives are launched for continuing progress in the economic competitiveness, reliability, and safety of nuclear plants around the world. ❐