Institute for Energy

Workshop on "Maintenance Rules: improving maintenance effectiveness"

organized by
EC/JRC (SENUF), Iberdrola, Soluziona, Tecnatom,
UNESA & EPRI,
on 19-22 June 2006, at UNESA, Madrid

Summary Report

Paolo CONTRI

DG JRC – Institute for Energy

November 2006

SENUF

Safety of Eastern European Type Nuclear Facilities

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Executive Sumary

This report deals with the technical summary of the presentations and panel discussions in relation to the workshop on “Maintenance rules: improving maintenance effectiveness” which was organized in Madrid (UNESA premises) on June 19-21 by the JRC-IE (SENUF network), UNESA, EPRI, Iberdrola, Soluziona and Tecnatom.
The purpose of the workshop was to examine current practices used by nuclear power plants utilities to assure proper and effective maintenance and to discuss the future needs that must be met to continue to foster effective maintenance. In fact it was recognized that improving the maintenance program is one of the best tools to improving overall plant performance and cost control, even improving its overall safety.
The conclusions of the workshop were focused on the Implementation methodology for maintenance rules, Regulatory aspects, and Equipment reliability analysis. Few notes complement the summary of the workshop with comments on the applicability of the workshop conclusions to the nuclear plants in the Central and Eastern Europe.
The workshop concluded that there is a potential, very important role for the SENUF/SONIS network in the coordination of the efforts among the European Countries, as the implementation of a “maintenance rule” requires the availability of component data, well assessed probabilistic techniques and other techniques that cannot be developed at the Country level. In this framework, any future action in the FP7 would be most probably very welcome.

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1. Introduction

According to the SAFELIFE Work Program for the year 2006, a deliverable was planned on the following:

5.09 Report on organizational models for Plant Life Management suitable for existing VVER nuclear power plants (excluding VVER 440/230 model), aiming at keeping these plants in safe condition in short and long-term

As expected, this deliverable was developed in the framework of the activity of the **SENUF** (Safety of eastern European type NUclear Facilities) network, and it represents the outcome of task 4 (Workshop on maintenance rule application) according to the SENUF Workplan for 2006 [1].
Moreover, this report refers to the conclusions of the SENUF report for Task 1 (Integration of MS&I programs at the plants, decision making process, organization) [2], where recommendations were issued on the continuation of the research in relation to three main areas in the field of the maintenance optimization, namely: integration of MS&I programs at the plants, decision making process, organizational aspects.

The workshop on “Maintenance rules: improving maintenance effectiveness” was organized in Madrid (UNESA premise) on June 19-21 by the JRC-IE, UNESA, EPRI, Iberdrola, Soluziona and Tecnatom.
The conclusions of the workshop were focused on the Implementation methodology for maintenance rules, Regulatory aspects, and Equipment reliability analysis. Few notes complement the summary of the workshop with comments on the applicability of the workshop conclusions to the WWER plants.

2. Summary of the workshop

Eighty delegates from European and American Organisations (EPRI, INPO), expert in maintenance programs and component reliability. The JRC-IE facilitated the participation of some SENUF members and other Eastern Countries representatives (Krsko NPP, Paks NPP, Czech Rep., Slovak Rep., Russia, Ukraine). Unfortunately no participation was recorded by Western European utilities, except Spain and Belgium.

The purpose of the workshop was to examine current practices used by nuclear power plants utilities to assure proper and effective maintenance and to discuss the future needs that must be met to continue to foster effective maintenance. In fact it was recognized that improving the maintenance program is one of the best tools to improving overall plant performance, even improving its overall safety.
The workshop was organized in the following sessions and had three parallel group sessions for organizational aspects, maintenance rules and tools to optimize maintenance, respectively:

1. The maintenance rule methodology;
2. Relation of maintenance rule with other maintenance related processes
3. Equivalent methodologies in other countries
4. Tools for measuring maintenance performance

An interactive session with four working groups enabled a broad exchange of experience among the participants.
Proceedings were issued in a CDRom by ENDESA (**SENUF Chairman**). In the following, the most important issues addressed at the Workshop are presented and

discussed.

1.1 The MR methodology

The history of the maintenance rule (MR) is important to understand the relationships with other related programs/issues. Many presentations by EPRI clarified the milestones of this process. In particular, they reminded that in the USA the MR started with a first detailed Rule issued in 1988. The Final Maintenance Rule was issued in July 1991, including the first performance-based rule and the first risk-informed rule, as Section 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants". The main objectives were

- Provide the industry with a performance based or results-oriented rule
- Improve the overall effectiveness of maintenance programs

The effective date of enforcement was July, 1996, after two years of guidance development and three years of pilot implementation.

In parallel, the NUMARC 93-01 Guideline was developed in 1992 with a broad industry participation. In June 1993 it was endorsed by RG 1.160. During 1994 -95 the NRC carried out pilot visits at 9 plants and in 1996 -1998 the NRC conducted the baseline inspections after completion of the implementation.

Some modifications to the reference text followed, as result of the pilot application, namely:

- In June 1993 the so called "(a)(3) assessment" was changed from annual to once/cycle, NTE24 months
- In July 1996 the MR applicability to permanently shutdown facilities was clarified
- In July 1999 (effective Nov. 2000) the MR became compulsory, the Licensee was formally charged to assess and manage risk and certain LSS SSCs were excluded
- In November 2000, the MR was modified by the addition of paragraph (a)(4) which went into effect November 28, 2000.

In particular with the last modification, the MR became "performance based" and "result oriented".

In relation to the scope of the MR, it addresses the following items:

- Safety-Related
- Non-safety-related used to mitigate accidents or transients
- Non-safety-related used in Emergency Operating Procedures
- Non-safety-related whose failure prevents safety-related SSCs from fulfilling their function
- Non-safety-related whose failure could cause a scram or actuation of a safety system

An expert panel is expected to evaluate the effect of scoping every item in relation to its contribution to the overall risk (CDF, etc), also during shutdown. The definition of "risk significant" item was provided and the three main performance criteria for SSCs were discussed: availability, reliability and condition monitoring. They are required for all risk significant SSCs and standby non-risk significant SSCs.

For the component in the "critical list" (the so called (a) 1), also goals are set, their monitoring procedures, and the corrective actions, as defined in the NEI docs. The procedure is applied to the system Level, the train Level, the component Level and the structure Level.

The very last step of the development of the MR approach, though not mandatory yet, is the attempt to systematize the whole programs into the “equipment reliability” program, described in the INPO AP-913 documents.
The document AP-913 addresses additional considerations compared to the MR, namely: Power Generation, License Renewal and High Cost Components. It prioritizes all equipment reliability related activities, utilizes multiple plant functions and coordinates their individual activities.

In conclusion, the reference documents applied in the USA are the following (a comprehensive list of references is available in the previous SENUF report [2]):

- NUMARC 93-01 (Rev. 3)
- RG 1.160 (Rev. 2, endorsed 93-01)
- NUREG-1526 (NRC pilot plant visits)
- NRC IN 97-18 (NRC MRBI observations)
- NUREG-1648 (MRBI lessons learned)
- RG 1.182 (endorsed NUMARC 93-01, ¶11.0).
- NEI 96-03 (Structural Monitoring)

In the US the maintenance planning is mainly based on INPO03-004 + appendix F of INPO AP-928 and NEI96-07. The asset management is developed in INPO AP913.

1.2 Relation of maintenance rule with other maintenance related processes

The Spanish approach to MR was described in detail. MR became effective in Spain in April 1999, being included as one of the NPP Exploitation Provisional Permit requirements.
The main differences with the EPRI/NEI approach are in the definition of the performance criteria and in the “improved” balance between availability and reliability of the components.
The maintenance planning practice is mainly based upon INPO 03-004, some appendixes to INPO AP-928 and NEI 96-07. The crucial connection with the asset management is described in the INPO AP-913.
Use of PSA for SSC classification: it represents a widely used practice nowadays. Many components have been re-scoped according to probabilistic criteria and a better consistency among the many different lists used by the different programs (ISI, MR, LTO, AMP, safety class, seismic class, etc.) has also been achieved.
The model proposed in the Equipment Reliability process (AP-913) looks very attractive. The scope is larger than the MR and it optimizes the plant capacity factor explicitly. In particular, it addresses the correlation among the existing safety programs at the plant in order to get a control of the overall plant reliability. The SSCs are classified in a different way then in the MR: “important”, “critical”, “run-to-failure”, avoiding potential conflicts with the safety classifications.

1.3 Equivalent methodologies in other countries

In Europe the application of MR at NPPs is still mainly on voluntary bases. However, a “prescriptive” regulation in this sense may not be appropriate for some countries with regulatory regimes other than the US. However, the engineering rationale behind the MR makes it attractive for other countries in Europe. For example, Spain, Slovenia, and Hungary already implemented part of the MR at their NPPs, while others think about future implementation (Czech Republic, Slovakia, Bulgaria, and Ukraine).

Some implementation issues of the MR in non-US plants were recorded, namely:

- Component classification: the approach proposed in the EPRI rules is sometimes difficult to apply, especially in case of repetitive failures, design failures, etc.
- Organizational framework: the historical organization in many Countries does not fit the proposed organization by the US docs.
- The applicability of the NUMARC 96-01 performance criteria is not automatic to other plants/components
- The maintenance of the digital I&C cannot be carried out according to the US standards, that, in fact, do not foresee such equipment
- The management of the plant modifications make the application of the MR quite complex: the failure modes are changed and in principle the whole system should be updated every time

1.4 Tools for measuring maintenance performance

Recent statistics carried out in the USA (INPO) show that 40% of the failures are related to human factors: among them, 30% are related to engineering deficiencies an 30% to work performance. Most of the significant events in the latter category have been triggered by the supplemental workers. Therefore the contractor performance becomes a crucial issue where many utilities are investing large effort for their reduction. Also supplier reliability is an issue: in many cases equipment were delivered with wrong or different specifications.

Performance indicators were extensively discussed, as based upon: ownership, time from exceedance of the performance criteria and setting of new goals, # of returns to “a1” list, site awareness, use of MR to drive performance, etc. Many Countries use the availability and reliability concepts defined in the MR also to monitor the performance of the ageing management programs (AMP).
A special group of indicators was presented on the “supplemental workers” and the “supplier reliability” in general, by INPO. They are recognized as very useful to monitor one of the main causes of deficiencies in the maintenance systems (they are included for example in the AP-930)

The techniques for the risk monitor during maintenance were discussed, mainly in relation to the NUMARC 93-01 (rev.3) proposal. The use of panel of experts and/or PSA for the construction of the risk matrix or of the risk monitor (real time) are apparently the only two available techniques. Software tools are available by Tecnatom and EPRI: ORAM-Sentinel, EOOS, SAFETY MONITOR.

Some data bases are available on component reliability: the experience of DACNE for PSA failure probabilities and for MR performance criteria (by Tecnatom), the EPIX (by INPO) and the PKMJ (by EPRI). However, most of them remain country specific and/or restricted to the contributing users.

It was recognized that no tools are available yet to manage the maintenance process in a comprehensive manner, even if the EPRI proposals are excellent in some fields. The user groups (EPRI/NMAC, EPRI/MRUG, etc.) are providing an invaluable contribution to this concern.

2 Comments from the working groups

Additional comments (not included in the proceedings) were issued after the working

group wrap-up.

- It was clarified the difference between the a1 and a2 group of SSCs (structures, systems and components) according to the US standards: they are mainly related to the performance criteria and the setting of performance goals.
- The implementation of the MR poses major challenges to the organization: in some cases the interfaces among existing departments were so many that new structures had to be developed. In other cases (Spain) the organization did not change and only the coordination was improved. Also in the US, the objective of the action was the re-definition of the interfaces. It was pointed out how the interfaces are very sensitive to the changes in plant configuration and should be promptly updated in such cases.
- The development of suitable performance criteria is a crucial task. In Spain three years of historical data fed the statistical analysis, complemented by the PSA. In the USA the process was also reviewed by the regulator. The digital I&C cannot be monitored easily in time. Therefore the failure rate usually is provided by the supplier who can derive it on the basis of the whole population of the installed equipment.
- There is no shared data base on maintenance among NPPs. Only INPO and WANO provide a worldwide service to their members. There are confidentiality issues attached to it, national factors and plant dependent issues that still prevent such communication. Neither non-nuclear plants are involved in this exchange of experience. Some maintenance forum (such as EPRI/NMAC) provides a certain level of experience exchange, however again restricted to members.
- The interfaces between ISI databases and MR databases are still poor, due to their history: ISI data bases are mainly related to passive components, MR to the active ones.

3 Considerations on the applicability of the workshop conclusions to the Central and East European plants

In general, the Ukrainian, Slovenian, Czech, Russian representatives expressed their interest to adopt a MR-like approach in their Countries, even starting on a voluntary bases, most probably closer to the ”equipment reliability” model (AP-913). Many of them already created some training centers which are developing procedures in this direction. All of them called for a better coordination in Europe and for new approaches, more tailored on the European practice. The Spanish experience in this framework is invaluable, thanks to both its advanced status of implementation and to its mediation of the US standards into the European context.

The “equipment reliability” program is not mandatory in most of the Countries (including the US). However, it is gaining growing interest for its systematic approach to the management of the plant safety. In particular, the correlation among the many existing safety related programs and the consistent classification of items (important, critical, run-to-failure) seems to be very attractive and practical.

More specifically, the national contribution/issues/vision are described in the following chapters.

3.1 The Ukrainian approach

The Ukrainian contribution at the Workshop highlighted the following:

1) There is high contribution to the plant risk coming from the human factors, included those related to the supplemental personnel.
2) The Energoatom headquarters developed a statistics for the causes of the mechanical failures. The conclusion can be summarised as in the following:
    - 40% of failures could be avoided by appropriate design/installation modifications of the equipment
    - 30% of failures could be avoided by a strict implementation of a refined maintenance approach, such as MR or the equipment reliability model (AP913)
    - 30% of failures could be avoided by an improved training of maintenance personnel

Therefore, there is generic tendency to implement the AP913 model, due to both its systematic approach to component reliability and improved (more effective, simplified) management of the process, if compared with the MR.
The approach could be applied without substantial modifications. However, a crucial issue remains the development of the component target reliability levels, which many plants still do not have.
A state-of-the-art national training facility was recently inaugurated with the support of the EC.

3.2 The Czech approach

A project to turn the current system towards a risk based one is fully in progress at the Czech Utility. In particular, a central maintenance system, dedicated to the definition of the strategic goals, procedures and approaches is under settlement at the headquarters, while the power plants retain the management of the daily work and the feedback collection. Such central organisation will take care of the conventional power plants as well.
The system of the contractors is also under review as in most cases there are large contracting companies, almost without competitors, with small in-house engineering and with no experience transfer with other contractors.
A major effort aims at shortening the outages, through improving the work coordination and reducing the frequencies of the necessary revisions.

3.3 The Russian approach

The optimisation effort at the Russian plants is mainly spent in the optimisation of the maintenance schedule and in the review of the testing levels for the equipment. In this framework, the involvement of the design and research organisations (Gidropress, Vniaes, etc.) is dominant.
The criteria applied in the optimisation are the probability of equipment failure, the core damage frequency and the probability of release.
Therefore the optimisation process is mainly based on PSA application, with significant reduction of doses, manpower and costs.

3.4 The Slovenian approach

The MR is not a regulatory requirement in Slovenia (at Krsko NPP). However, it is applied at the Utility, considering the positive effect on the plant management, safety and cost control. It has been applied since 2001, even if performance criteria are not formally established yet in accordance with NUMARC 93-01 requirements. However, periodic adjustment of the performance criteria on the basis of the reporting system is carried out.

Quarterly MR/System Health Report (SHR) is forwarded also to Slovenian Regulatory Body.
The MR Program is incorporated in other plant programs, such as:

- System Health Reports (SHR)
- Corrective Action Program (CAP)
- Preventive Maintenance Program (PM Program)

The Aging Management Program, which interfaces with the life time extension program, has also many connections with the pilot application of the MR.

In Slovenia, the main features of the special version of the MR applied at Krsko are the following:

- Development of MR/SHR quarterly reports (for 37 systems, 8 + 3 SE)
- Use of MR Scoping Database and Risk Significance Determination Database incorporated in CAP
- Functional Failures (FF) reporting systems and action plan implementation through CAP with the following characteristics:
    - immediate response,
    - corrective action timely implementation)
    - transparent (any one could comment through CAP Forum)
    - effective approval process for corrective actions

- Appointment of a Maintenance Rule Coordinator (approximately 1/2 time)
- Appointment of a MR/SHR Expert Panel, which includes people with experience in the following areas: engineering (PRA/PSA), operations and maintenance, electrical equipment, mech., and I&C. A minimum of 5 years nuclear experience is required for each member of the Panel

In particular, the Expert Panel merges the results of the different programmes into system and component reports, and provides more engineering management to system and component engineers to really manage and influence the priorities in a long term planning, with the focus on the future performance rather than past performance.

Some challenges have been already identified for the short term improvement of the program, namely:

- A revision is needed of the current preventive maintenance program and its optimization; they will improve the technical basis for the maintenance activities and will provide useful data for future optimization. In particular, the revision of the work order process will optimize the feedback.
- Improvement of the MR in the long term planning process will support better planning of cycles, outages, and budgeting.
- Aging management review of passive components will affect preventive maintenance activities and improve the anticipation of safety issues,
- Revision of some performance indicators, which can serve as sub-indicators for the calculation of Equip. Reliability Index according to INPO definition.
- Trending of low level events to support the right decisions and affect long term plans and preventive maintenance programs. The analysis/coding of minor events and deviations is in progress through corrective action program.

3.5 The Hungarian approach

In Hungary the implementation of the MR was mainly triggered by the Plant License Renewal program for which the MR represent a pre-condition.
In this context, in 2003 the HAEA realised that the “preconditions for LR” were not

completely in place at Paks. In particular, the scoping of the SSCs was not systematic (only 14 main systems were included in the AMP), the maintenance system was not “trend oriented” and the degradation mechanisms were not analysed completely, no monitoring of the maintenance effectiveness was in place, equipment qualification was still supply oriented, design basis for many equipment was not available. Therefore, since 2003 the HAEA developed a set of regulatory documents at different binding levels and modified the existing high-tier legal documents to address the relevant licensing issues, to define the process characteristics, and to clarify the regulatory involvement and review actions. These documents include Codes (legally binding documents), Guidelines and Procedures.

According to the relevant guidelines, crucial attributes for maintenance programmes in order to support LTO are considered: the verification of the performance goals, the root cause analysis of failures, the feedback from maintenance to the ISI programme, the feedback on the OLC, etc. In particular, the following features are believed to be indispensable for a state-of-the-art maintenance programme, even if the LTO process is not urgent in the Country:

1. Monitor the performance of the SSCs which may have impact on safety during all operational statuses of the plants;
2. Assess and manage the risk that may result from the proposed maintenance activities in terms of planning, prioritisation, and scheduling.

The implementation of this version of the MR is still in progress at Paks NPP.

4 Conclusions

The workshop concluded that there is a potential, very important role for the SENUF/SONIS network in the coordination of the efforts among the European Countries, as the implementation of MR requires the availability of component data, well assessed probabilistic techniques etc. that cannot be developed at the Country level. In this framework, any future action in the FP7 would be most probably very welcome.

To this concern, the main interest was identified in the development of more efficient organizational models at the plant, in a more realistic evaluation of the component performance goals and of their dependency from time (ageing mechanisms), inspection frequency and quality, component availability, and indicators of the supplemental workers (supplier) reliability.

5 References

[1] Third Steering Committee Meeting (2005) of the “SENUF Working Group on Nuclear Power Plant Maintenance”, January 26-27, 2006, EC/JRC-IE - Petten (NL)

[2] EUR 21903 EN: “Optimization of Maintenance Programmes at NPPs - Benchmarking study on implemented organizational Schemes, Advanced Methods and Strategies for Maintenance Optimization - Summary Report”, January 2006

6 List of Abbreviations

ACC	Acceding and Candidate Countries
AMP	Ageing management program
CFR	Code of Federal Regulations
CIS	Commonwealth of Independent States
CM	Corrective Maintenance
EPRI	Electric Power Research Institute
EU	European Union
IAEA	International Atomic Energy Agency
IE	Institute for Energy
ISI	In-Service Inspection
I&C	Instrumentation & Control
LTO	Long Term Operation
MS&I	Maintenance, Surveillance and Inspection
NPP	Nuclear Power Plant
PLEX	Plant Life Extension
PLIM	Plant Life Management
PM	Preventive Maintenance
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review
RBI	Risk Based Inspection
RCM	Reliability Centred Maintenance
RG	Regulatory Guide
RIM	Risk-Informed Maintenance
SENUF	Safety of Eastern European Type Nuclear Facilities
SSC	Systems, Structures and Components
TS	Technical Specifications
VVER (or WWER)	Water-Cooled Water-Moderated Power Reactor

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Abstract
This report summarizes the presentations and the outcome of the panel discussion in relation to the workshop on "Maintenance rules: improving maintenance effectiveness" which was organized in Madrid (UNESA premises) on June 19-21 by the JRC-IE (SENUF network), UNESA, EPRI, Iberdrola, Soluziona and Tecnatom.
The purpose of the workshop was to examine current practices used by nuclear power plants utilities to assure proper and effective maintenance and to discuss the future needs that must be met to continue to foster effective maintenance. The workshop confirmed that improving the maintenance program is one of the best tools to improving the overall plant performance and the cost control, even improving the overall plant safety.

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