Experience with maintenance and periodic tests in German NPPs and the influence on safety

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Abstract:
The performance of maintenance represents an important safety aspect of nuclear power plant. Maintenance can be defined as all measures for the preservation and restoration of the specified designed state and for the identification of the actual state. In German NPPs the maintenance concept is a mixture of preventive planned and state oriented maintenance. A special aspect of the maintenance is the “preventive maintenance on the Safety System during power operation”.

Periodic tests on safety relevant systems and components are an established and proved part of the maintenance concepts. They serve to assess the correct state and functional condition of the systems or its components by comparing the actual state detected during the tests with the specified designed state. The purpose of periodic tests is to find out, whether the respective test objective fulfills the specified qualitiy characteristic e. g. the functional condition or tightness. Additionally it has to be shown that these qualitiy characteristic will be fulfilled until the next test is carryied out. This way all relevant properties on the safety of NPPs have to be verified periodical. Despite the fundamentally positive experience with periodic tests, als insufficiency and disadvantages of periodic tests were recognized, so a review of the periodic test programmes has been realized.

1 GENERAL REQUIREMENTS ON THE SAFETY OF NUCLEAR POWER PLANTS

When you discuss about the safety of a nuclear power plant (NPPs), you always have to think about the fundamental safety functions which have to be fulfilled at any time. The three fundamental safety functions of any nuclear reactor are (according to IAEA):

- safe shut-down and safe power reduction of the reactor (reactivity control)
- safe residual heat removal from the reactor
- safe enclosure of radioactive materials

All systems, structures and components in a NPP required to fulfill these safety functions are part of the Safety System. Examples for systems of the Safety System of NPPs are

- Reactor protection system (PWR/BWR)

- Residual heat removal system (PWR/BWR)

- Containment penetration isolation valves (PWR/BWR)

- Ventilation systems (PWR/BWR)

- Boron injection system (PWR)

- Reactor trip systems (BWR)

- Emergency feed water system (PWR)

- Emergency Power supply (PWR/BWR)

Systems which have no safety functions are part of the operating systems. Examples for these systems are

- Condensate systems (PWR/BWR)

- cooling water system for operating systems (PWR/BWR)

- demineralizing plant (PWR/BWR)

Maintenance and periodic tests are performed for all systems and their components. The safety related importance of the system and its importance to the availability of plant operation defines the scope of activities.

2 MAINTENANCE AND PERIODIC TESTS

2.1 Definition of Maintenance and Periodic tests

Maintenance can be defined as all measures for the preservation and restoration of the specified designed state and for the identification of the actual state. Maintenance activity is divided into repair work (e. g. the replacement of faulty parts), servicing (e. g. greasing and oil change, exchanging parts damaged by wear and tear) and inspection (e. g. functional tests and visual inspections).

Periodic tests are an approved part of maintenance activity. They serve to assess the correct state and functional condition of the system or its components by comparing the actual state detected during the tests with the specified designed state. These periodic tests are carried out for all components which are part of the Safety System and the operating systems. That applies to stand-by systems/components as well as to systems/components which are continuously in operation. But the focal point of the periodic tests lays on systems and components that are in stand-by mode.

2.2 General aspects on Maintenance and Periodic tests

Undetected faults and a loss of function can be minimized by using a maintenance concept and by the performing of periodic tests. Moreover, this procedure gives the possibility to check whether the operating systems work correctly in order to avoid actions of the Safety System. Using this procedure for the Safety System helps to check its functional condition so that it works correctly in case it is required.

Thus, the performance of maintenance measures and the performance of periodic tests represents an important safety aspect of a NPP.

TÜV Industrie Service GmbH, TÜV SÜD Group has a long-time experience in maintenance and periodic tests and has been involved in the development of the maintenance concepts and the concepts of period tests in regard to the observance of the safety requirements. We are involved in the carrying out of the corresponding activities in 11 NPPs with regard to a safety related assessment of the results gained by the maintenance measures and the periodic tests (see Fig. 1).

Plant	Electrical power	Start of commercial operation
NPP Isar 1 (KKI 1)	912 MW	1979
NPP Philippsburg 1 (KKP-1)	926 MW	1979
NPP Gundremmingen (KRB-II) Unit B Unit C	 1344 MW 1344 MW	 1984 1985
NPP Obrigheim (KWO)	357 MW	1968
NPP Neckarwestheim 1 (GKN-I)	840 MW	1976
NPP Biblis Unit B (KWB-B)	1300 MW	1977
NPP Grafenrheinfeld (KKG)	1345 MW	1982
NPP Philippsburg 2 (KKP-2)	1455 MW	1984
NPP Isar 2 (KKI 2)	1475 MW	1988
NPP Neckarwestheim 2 (GKN-II)	1365 MW	1989

Fig. 1: TÜV Industrie Service GmbH, TÜV SÜD Group:
Involved in this NPPs regarding to maintenance and periodic tests

3 MAINTENANCE

3.1 Importance of Maintenance

To combine high availability of NPPs with the requirements of safety, a maintenance concept is necessary. In principle, there are three different concepts of maintenance:

- a preventive (planned) maintenance with regular intervals

- a state oriented maintenance (using systems for measuring vibrations, temperatures, pressures etc.)

- a failure oriented maintenance (after a failure).

In German NPPs, the maintenance concept of the Safety System is a mixture of preventive and state oriented maintenance.

The maintenance of the Safety System and the operating systems in a NPP is performed during power operation and during outage by the operators of the NPPs. Independent experts are involved in the maintenance of German NPPs Safety System during power operation and during outage. As far as possible, servicing and inspection is done at the same time to reduce costs. A special aspect of maintenance is the preventive maintenance on the Safety System during power operation (PMPO).

3.2 Preventive Maintenance on the Safety System during Power Operation (PMPO)

3.2.1 Definition of PMPO

Preventive Maintenance on the Safety System during Power Operation (PMPO) can be defined as measures, which

- are applied to the Safety System
- are carried out during power operation
- allow the examination of the actual state
- ensure or restore the designed state
- result in a temporary unavailability of the Safety System or parts of it

Since 1997 in all Bavarian NPPs (KRB II – Unit B & C, KKI 1, KKI 2, KKG) it is licensed to carry out PMPO.

PMPO is only allowed on stand-by systems with the degree of redundancy n+2 (e. g. emergency feed water system, residual heat removal system, emergency diesels & generators). On stand-by systems with the degree of redundancy n+1 PMPO is only allowed under special conditions (measures of compensation) and/or in case that no single failure criterion has to be applied and a safety assessment shows that it would be permissible. An example for components of a system with the degree of redundancy n+1 are the inner and outer containment penetration isolation valves.

3.2.2 Basic Requirements for establishing PMPO

The influence of PMPO on plant safety has to be analysed and evaluated (preferably using probabilistic safety assessments). To guarantee constant plant safety, the loss of availability of safety functions caused by PMPO is to be compensated, e. g. by carrying out additional functional tests of the other redundancies a short time before starting PMPO. Tolerable unavailability times are to be determined.

Preventive measures have to be put into action to avoid the influence of PMPO on other redundancies or safety components (especially for older NPPs with interconnected systems). The common basic requirements are to be laid down in the safety specification of the operating manual, the details are to be regulated in so-called “PMPO-Instructions”.

3.2.3 General conditions for carrying out PMPO

PMPO can only be carried out for one redundancy of the Safety System at the same time while the other redundancies of the Safety System must be available. Regarding the other redundancies, only necessary works (e. g. periodic tests without influence on the availability or urgent repair works) are allowed. After PMPO, a functional test of the system or the affected parts of the system must be carried out, to ensure its availability.

3.3 Experience with PMPO

PMPO allows to carry out maintenance on redundant systems by different personnel at different times (to avoid common cause failures resulting from maintenance faults). PMPO allows an intensive supervision by the operators personnel and a better knowledge transfer from the specialists of the maintenance company to the operators personnel (better quality assurance than during outage). The past experience has shown good results, no relevant problems have occurred.

3.4 Influence on safety

Necessary activities can be performed without the interference with other measures (as opposed to an outage). By consideration of the basic requirements and the general conditions for carrying out preventive maintenance on the Safety System during power operation, there is no inadmissible influence on the safety of the plant. By order of the state authority the independent experts of our company have to verify that the basic requirements and the general conditions are met by the operator of the NPP. With PMPO, an increase of reliability is possible without affecting the integral safety of the plant.

4 PERIODIC TESTS

4.1 Importance of Periodic tests

Periodic tests of the safety features are part of the safety precautions of NPPs and are carried out at regular intervals (e. g. weekly, monthly, yearly).

Periodic tests are important to verify that systems and their components are available to perform their safety functions. By carrying out periodic tests, it is possible to detect the first signs of a deterioration of the system functions before failures occur. This applies especially for equipment which is normally in standby mode.

The importance of the periodic tests is shown by the failure statistics and the malfunctions detected by the tests.

Concerning testing methods, the tests can be divided into the following types:

- Functional tests (systems/components)

- Visual tests (inner and outer)

- Pressure tests

- Leakage tests

- Non-destructive material tests

Periodic tests are applied to all safety related installations of NPPs, such as mechanical hardware (e. g. components of the residual heat removal system or the boron injection system), power supply (e. g. emergency diesels and generators), control systems (e. g. reactor protection system) and radiation protection (e. g. measuring instruments).

4.2 Experience with Periodic Tests

Operational experience shows that in most cases, periodic tests proved the reliability of the tested systems and components. Malfunctions were detected before severe damages or consequences occurred (e. g. detection of cracks in pipes without penetrating the complete section thickness). Despite the fundamentally positive experience with periodic tests, also insufficiency and disadvantages of periodic testing were recognized in some cases. An example for this are cracks in austenitic pipes in BWRs which were not detectable with the applied test procedures. For an other example the tests of the residual heat removal led to vibrational stress (caused by the starting of a high-pressure pump and actuating a valve) and resulted in a cracking in a joining pipe.

Additionally, improvements were made in diagnostic techniques, monitoring and computer based operational data management systems e. g. the implementation of thermal fatigue monitoring systems.

Summarizing the operational experience gives indications that there is still a potential for optimisation of the test strategy and procedures. Therefore a review of the periodic test programmes started in the early 90´s in all Bavarian NPPs.

4.3 Procedure for Reviewing the Periodic Test Programmes

The procedure for the review includes the following steps:

- Assessment of the relevance of the systems/components to the safety (PSA)

- Compliance with the relevant regulations e. g. “the technical safety regulations” of the German Nuclear Safety Standards Commission (KTA)

- Importance of the tests and its effects e. g. on the plant

- Consideration of the operating experience and external experience e. g. advisory messages of the GRS

- Completeness of the tests (all features of the system have been taken into account).

The procedure was put into practice within the scope of “work packages”, which include e. g. the complete residual heat removal system, the secondary circuit of a PWR and the emergency power supply. The reason for this procedure was that for each working package, a closed safety evaluation of the maintenance concept should be achieved and not only single measures of individual parts or components. This should guarantee that the modifications to the test programmes lead to an improvement of the overall safety of the plant.

Considering this procedure some deficits were identified for each plant, therefore recommendations for completing the test programmes were made (e. g. the additional testing of alarm signals and components or functions, which were not tested previously). During the investigation, it was found that often one and the same component was tested more than once at virtually the same time because of actuation by different test signals. Thus, a recommendation was made to alter the time schedule. Internal visual inspections of components (e. g. valves or pumps) are very expensive and sometimes associated with a high radiation exposure. To reduce the high maintenance costs and the dose rate, the NPP-operator tries to extend these test intervals. The investigation shows that this is possible without reducing the plant safety e. g. by using monitoring systems as compensation measures. The proposed changes to the periodic test programmes were investigated with the PSA method, as far as possible.

4.4 Experience with the Reviewed Periodic Test Programmes

The review of the test programmes produced different insights, which are shown below:

- The review of the tests can take them to the current technical state of the art.

- Optimisation of the test procedures can lead to less wear of components.

- New test methods can help to reduce the costs associated with testing (completing or replacing tests by diagnostic or monitoring systems).

- Test intervals can be extended without influencing the safety of the plant under the condition of performing compensation measures (e. g. by carrying out a diagnostic test to verify the operability of a valve).

- Reviewing of tests can lead to an improvement of plant safety and to a reduction of maintenance costs.

In summary, it is beneficial to review the test programmes and it is recommendable to repeat such a review after some time.

4.5 Influence on safety

With the optimisation of the periodic test programmes, the safety of the plant can be increased because gaps in the test strategy and errors in the performance of the tests can be determined and new, advanced test methods can be applied. With the chosen procedure a closed safety evaluation of the maintenance concept has been achieved. This guarantees that the modifications to the test programmes can lead to an improvement of the safety of the plant. By order of the authority the independent experts of TÜV SÜD have to verify, that the reviewed periodic test programmes meet the requirements of safety.

5 CONCLUSION

Maintenance and periodic tests are part of the safety precautions of NPPs.

The experience with maintenance including preventive maintenance on Safety Systems during power operation is generally good. At present the maintenance concepts in German NPPs are changing towards state oriented maintenance by using new methods of surveillance. The experience with periodic tests is also good but shows a potential to optimise the test strategies and procedures to improve safety.

In summary, maintenance and periodic tests are of great significance to the safety of NPPs and this is shown by the high availability of German NPPs. Even though the concepts for maintenance and test strategies are essentially well-tried, a permanent improvement and optimisation of the concepts and the strategies is useful and sometimes necessary.