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A METHODOLOGY FOR SEISMIC UPGRADING OF NUCLEAR POWER PLANTS

A. Gürpinar

International Atomic Energy Agency, Nuclear Safety Division, A-1400 Vienna, Austria

1. ABSTRACT

This paper is the product of a meeting of a number of international specialists on the topic of seismic upgrading of nuclear facilities held at the IAEA in 1992. Its purpose is to provide guidance on the methodological aspects of a seismic upgrading program for a nuclear power plant.

An overview of a procedure which is recommended to assess and enhance the seismic capacity of existing VVER reactors is provided. Major focus of this procedure is to provide a cost-effective process which will allow to prioritize and implement needed modifications in a timely manner, using the realistic assessment of responses and capacities.

Major technical elements of this procedure are: (1) identification of the most critical systems, components and structures needed for safe shutdown and to maintain safe shutdown; (2) evaluation of as-built conditions through data gathering activity such as review of design drawings and construction specifications and detailed walkdown; (3) realistic assessment of plant response and capacity evaluations for developing acceptance criteria and designing cost-effective fixes, and (4) functional qualification of active mechanical and electrical components through use of generic test data applicable to all VVERs, plant-specific tests and earthquake experience data.

This procedure is sub-divided into three major categories: equipment, structures and distribution systems for prioritizing design and implementation of needed fixes. Some fixes, such as anchorage upgrade, are easily identifiable and could be designed for conservative seismic demand. This demand would be confirmed after a detailed plant response analysis is completed. Other fixes involving major structural elements or complex load paths would necessitate realistic response evaluations as well as capacity evaluation to design cost-effective fixes.

The paper provides several examples of the implementation of this methodology to nuclear power plants in Eastern Europe within the framework of IAEA projects.

2. BACKGROUND

As the ratio of the number of operating nuclear power plants to those in the stages of siting and design has continually increased within the past fifteen years, the emphasis of nuclear safety related to external hazards has also shifted to existing facilities.

In this context, methods have evolved to re-evaluate seismic input parameters for existing sites as well as seismic capacities of structures, equipment and distribution systems of nuclear power plants with the purpose of seismic verification and possibly upgrading.

Within the past several years the IAEA has been requested to conduct seismic safety review services of existing nuclear power plants (under construction or in operation) in particular in Eastern Europe and the countries belonging to the Commonwealth of Independent States (CIS). A summary list of these reviews is presented in Table 1.

The following general observations have been made in relation to these reviews:

(1) Most of the reviewed NPPs under construction or in operation are under-designed for the required seismic input. Some require substantial work to demonstrate geological stability in the site vicinity.
(2) Verification of seismic design is often difficult due to lack of documentation and as-built drawings.
(3) Use of newly evolving methods such as plant walkdowns, experience data, HCLPF, etc. are cost-effective in the assessment and prioritization of corrective actions and remedial measures (i.e. seismic upgrading).
(4) Phasing of actions is very important due to:
    - Requirement for the calculation of a Review Level Earthquake on the basis of seismotectonic data and in compliance with current international practice. This may take several years of field and analytical work.
    - Urgency in actual hardware fixes for an operational plant which generally should not wait until the finalization of the Review Level Earthquake.

It was within the framework that a Coordinated Research Program (CRP) was initiated at the Nuclear Safety Division of the IAEA with overwhelming support from the countries of Eastern Europe, Western Europe, Russian Federation, U.S.A. and Japan.

Two meetings were held in Vienna in 1992 for the planning of this CRP which produced a working document summarizing the intended methodology for the Benchmark Study for Seismic Analysis and Testing of WWER Type Nuclear Power Plants as well as a plan of project implementation.

The benchmarking will be focused on two specific prototypes, i.e. Kozloduy NPP, Unit 5 or 6, for WWER 1000 Mw and Paks NPP, Units 1-4, for WWER 440/213 Mw. It is intended to perform dynamic analyses and tests on selected structures, equipment and distribution systems of these prototype plants, in order to generalize and recommend to other owners of similar plants a plan of action to verify and upgrade these.

3. METHODOLOGY OUTLINE

During the two preparatory meetings held in 1992, a flow chart was prepared describing an overall methodology for assessing and enhancing the seismic capacity of existing nuclear power plants. This flow chart is presented in Figure 1.

The aim of the assessment is to show that the plant can withstand a Level SL2 earthquake without giving rise to a Level V accident (on the INES Scale). This will be interpreted as ensuring that service condition D (as defined by ASME), or the equivalent, is not exceeded. If this is not possible, modifications will be identified that, when implemented, will prevent the occurrence of the Level V accident.

It should be noted that a Level V accident is defined as an "Accident with Off-site Risk".

As may be seen from Figure 1, after identification and classification of systems to be considered, the seismic input, soil data, acceptance criteria and loading combinations are established. Considerable effort and decision making is required to arrive at this point. In general, the seismic input is determined using the principles and methods established for new sites and plants. (See e.g. IAEA 50-SG-S1, Rev. 1, 1991). The only difference might be due to the "lifetime" of the plant, when the input is calculated on

Table 1. Seismic Safety Review Services

Month	Country	Plant	Service
March 1990	Poland	Zarnowiecz	Site Safety Review Mission with Limited Scope
April 1990	CSFR	Temelin	Site Safety Review Mission
June 1990	Bulgaria	Belene	Site Safety Review Mission
June 1990	Bulgaria	Kozloduy	Site Safety Review Mission
November 1990	Romania	Cernavoda	Review of Structural Nonconformities
April 1991	Bulgaria	Kozloduy	Seismic Walkdown, Unit 3
June 1991	USSR	Crimea	Seismic Safety Review Mission
October 1991	CSFR	Bohunice	Seismic Walkdown, Unit 1
February 1992	Bulgaria	Kozloduy	Review Mission - Seismic Input
March 1992	Slovenia	Krsko	Workshop - Plans/Procedures
April 1992	Bulgaria	Kozloduy	TOR - Seismic Upgrading
May 1992	CSFR	Bohunice	Seismic Walkdown: Follow-up
May 1992	Armenia	Oktemberian	Seismic Input Review and Plant Walkdown
August 1992	Bulgaria	Kozloduy	Seismic Upgrading Design Review
October 1992	Slovenia	Krsko	PSA Seismic Input Review
April 1993	Slovakia	Bohunice	Seismic Input Review - Plant Walkdown
May 1993	Pakistan	Karachi	Seismic Design Review and Plant Walkdown
June 1993	Bulgaria	Kozloduy	Seismic Upgrading Review
June 1993	Russia	Smolensh	Seismic Input Review and Plant Walkdown
September 1993	Bulgaria	Belene	Seismic Input Review
October 1993	Hungary	Paks	Seismic Design Review and Plant Walkdown
December 1993	China	Qinshan	Plant Walkdown

* Activities for 1993 are in planning.

a probabilistic basis. This is generally shorter for existing plants (if life extension is not envisaged) and may lead to somewhat lower design values.

The major difference with the seismic design of a new plant would be related to acceptance criteria, which would make use of existing safety margins to the fullest extent possible.

Beyond the evaluation of the situation and setting up of criteria, the methodology is specific depending on the plant item in question, i.e. structures, distribution systems and equipment.

Special emphasis is given to the "easy fixes" resulting from the structural evaluation of distribution systems and equipment, which, when implemented may increase seismic safety most cost effectively.

This has been already observed in the seismic upgrading of the Kozloduy NPP, Units 1-2, for which the IAEA has provided continuous support through review services including the preparation of the Terms of Reference (TOR) for the seismic upgrading program*. The TOR specifies four phases for the seismic upgrading of the Kozloduy NPP, Units 1-2, each phase increasing the safety level by implementation of "easier" fixes and assessing the seismic capacity of more complex items systematically. This eventually leads to the attainment of the seismic safety goal within a specified time frame.

The actual benchmarking of analysis and testing is mainly envisaged for structural systems in the beginning of the project. The method for the interaction of testing to analysis is presented in Figure 2.

* This program was funded by the European Community and executed by WANO.

It is planned to conduct full scale dynamic testing of the reactor structures of both the Kozloduy (Unit 5 or 6) and Paks (Unit 1, 2, 3 or 4) Nuclear Power Plants either in 1993 or 1994. Although some testing was already performed on these structures previously, it is envisaged to have a more systematic and integrated approach of testing for the benchmark study.

4. CONCLUDING REMARKS

The benchmark study under the IAEA Coordinated Research Program has drawn a great deal of interest from all concerned member states. It promises to serve as a forum for the exchange of ideas related to different analytical methods, codes, testing techniques and criteria all focused on the problem of assessment and enhancement of seismic capacity of existing nuclear power plants of the VVER type. It is expected that the results of the program will help in understanding the existing seismic safety level of these plants in terms of current international practice and provide guidance to the owners of these plant in improving this level.

5. REFERENCES

International Atomic Energy Agency, 1991, "Earthquakes and Associated Topics In Relation to Nuclear Power Plant Siting", NUSS 50-SG-S1 (Rev. 1), Vienna.

6. ACKNOWLEDGEMENTS

The article comprises a synthesis of the conclusions of two meetings in 1992 held in Vienna by about thirty international specialists whose valuable contributions both to this paper and to the Coordinated Research Program are gratefully acknowledged.

Figure 1. Chart for the Assessment and Improvement of Seismic Capacity

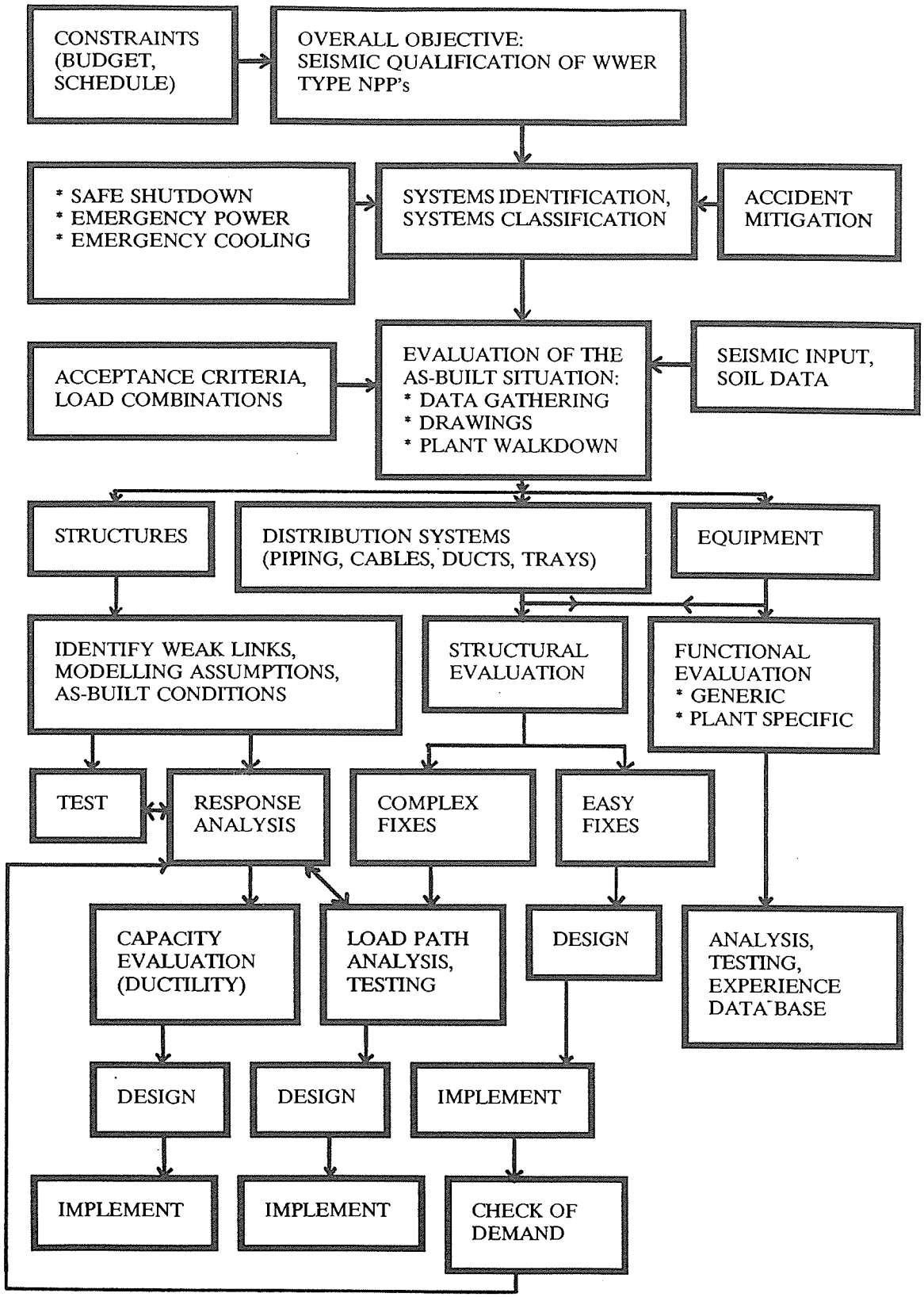

Figure 2. Interaction of Analysis and Testing