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International Expert's Meeting on Protection against Extreme Earthquakes and Tsunamis in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant (IEM3)

BOOK OF PAPERS

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METHODOLOGY OF DYNAMIC PARAMETERS CONFIRMATION, DETERMINING SEISMIC STABILITY OF NPP's ELEMENTS

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A seismic stability of constructions, having quite regular geometric forms, is quite reliably guaranteed in modern projects by the instrumentality of traditional calculating methods. A strength calculations reliability of power block's building is provided by its behavior as a rigid body under a seismic action. But it is incorrect for equipment and pipelines of NPPs.

A preliminary estimation are certainly needed to avoid a considerable mistakes, but seismic stability substantiation at the stage of designing can't ensure a total safety.

Firstly, even the most accurate models can't take into account all details and dynamic interrelations between constructive elements of equipment. Also, it's often not possible to take into account all manufacturing tolerances in rotating and sliding elements. Secondly, own dynamic characteristics (frequencies and decrements) of tested element are determined not only by its configuration and materials, but also by interrelated elements– supports, piping arrangement, heat-insulation.

A problem of fully exact boundary condition's determination is very hard to solve. The difficulties are also caused by the fact, that in some cases a number of pipe installation questions are solved during a mounting process.

Seismic loads on the NPP's equipment essentially depend upon both own frequencies and damping. Own frequencies are calculated on the stage of designing and verified by experiments, but this data such as damping characteristics, depending upon the conditions of mounting, bolting, conditions of interaction with other objects, such as supports, are not reliable.

In view of seismic impact resonant character a difference of 1 Hz between real own frequencies and calculated own frequencies can result in the mistake of seismic loads estimation up to several times. Our many years experience shows, that calculations without knowledge about own frequencies values gives very low accuracy of results. An error's value can reach a hundreds percents. A transferring of seismic stability analysis results from NPP's power block to another is absolutely unacceptable because of different forms of load's spectrum. Methods which offer to use universal spectrums of seismic loads with decrements of value 5% are also unacceptable. An inspections of many NPP's power blocks have shown, that in the number of cases a real values are lower than 2% and under the loading, comparable with real earthquake, this values increase no more than 1,5-2 times. Thus, using of decrement's value of 5% results in undervaluation of seismic loads.

Therefore, only the element-by-element testing method, including experimental evaluation of dynamic characteristics in the real conditions of fixing and piping arrangement with an implementation of compensating measures, can guarantee a seismic consistency of important to safety systems. Dynamic characteristics are evaluated using measurement instrumentation directly on NPP's power blocks in the conditions of real fixing, piping arrangement and heat-insulation. An analytical model is being corrected taking into account an estimated values of own frequencies and decrements, then recomputation is carried out.

An impact action used for the experimental evaluation of dynamic characteristics has to guarantee a safety of inspected constructions. Experimental loads have to be reduced by one or two orders in comparison with real earthquake forces. We use an impact method of

decaying oscillations exciting by damped local impact. We use the notebook for the registration and digitizing of original accelerogram. A digitized appearance allows us to process accelerogram with a fast Fourier transform. A received amplitude-response curve contains a number of peaks, corresponding to own frequencies.

We understand that experimental values of decrements, obtained at relatively low impact loads values, required by safety requirements of tested elements, can turn out to be underestimated because of an implication of some nonlinear elements and relations under the real seismic action. However, a decrement's value under the real earthquake action appears at most 60 % above than decrements values under our slight impact as was shown by the provided experiments. It results in seismic accelerations overvaluation up to 10-20 %, that is guarantee an additional strength margin.

This method is accepted on all levels of Russian government industrial regulation: in federal normative document NP-064-05 – "Atomic energy use objects external natural and industrial loads considering". The order of seismic safety inspection works is regulated by normative document of operating organization "Important to safety NPP's elements and systems dynamic characteristics validation procedure". This new document is accepted in state corporation "ROSATOM" from may 1, 2012 and it is obligatory for all NPP's power blocks built and prolongated. The methodology had been applicated on the newest Russian Power Block number 4 of Kalininskaya NPP. A number of 1204 units had been tested and the recommendations for providing of dangerous units seismic stability had been applied.

Methodology of dynamic parameters confirmation, determining seismic stability of NPP's elements

The Method is accepted on all levels of Russian goverment industrial regulation: in federal normative document NP-064-05 - "A considering of natural and industrial external loads on nuclear energy use objects".

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The Document was accepted in state corporation "Rosatom" from may 1, 2012 and it is obligatory for all "NPP's power blocks are built and prolongated. The Methodology had been applicated on the newest Russian Power Block number 4 of Kalinin NPP". A number of 1204 units had been tested and the recomendations for providing of dangerous units seismic stability had been applied.

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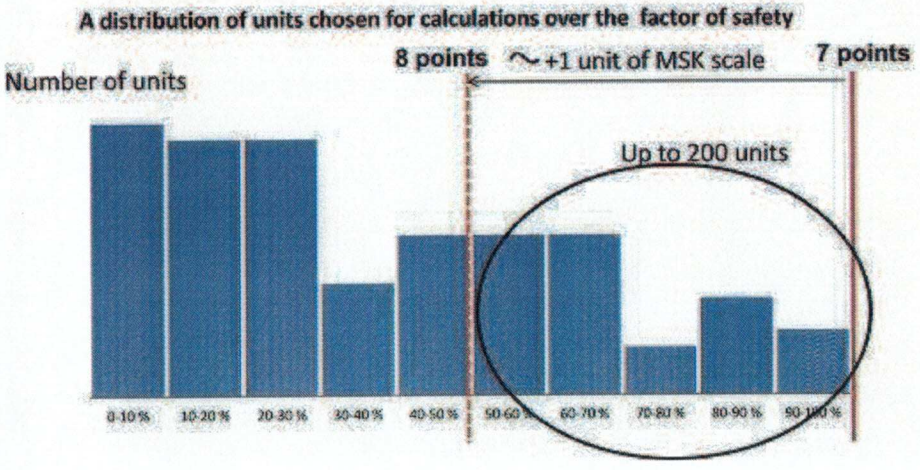
Kalinin NPP's 4th unit

All mechanocalorical equipment of seismic category 1 had been tested. Soil's acceleration of 0,1g corresponding 7 units of MSK scale. 97% of the equipment units are safe.



Previous works

The Method was implemented within the frameworks of two international IAEA coordinate programs on the Paks NPP, Kozloduj NPP and Leningrad NPP;

Many year's expirience and typical peculiarities of installed to NPP's systems equipment testing was taken into account during the Document development. There was 4000 units of 500 types tested,including all nomenclature of VVER 400, VVER-1000 and RBMK NPP's mechanocalorical and electrotechnical equipment.

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Russian normative documents

NP-031-01

"NPP's antiseismic desining codes"

5.2 A seismic qualification of equipment and pipelines under a seismic action defined by floor-by-floor accelerograms or by floor-by-floor responce spectrum have to be provided by computational and(or) experimental methods.

NP-064-05

"A considering of natural and industrial external loads on nuclear energy use objects"

6.13 Dynamic parameters (decrements and own frequencies) of systems and elements (except buildings and constructions) important to safety for safety providing on the stage of nuclear energy use objects commissioning have to be ivestigated by means of experimental survey or its dynamical testing in accordance with an order, a methodology, a scope of investigation set in the desin documentation.

Dynamic parameters of systems and elements important to safety for operating nuclear energy use objects have to be obtainded by the computational way and then to be confirmed by an investigations or by testing whthin an operatonal period on stopped and brought to a safety condition object (for example, during a planned shutdown).

An obtained values of redetermined dynamic parameters of important to safety systems and elements have to be used for a providing of nuclear energy use objects safety analysis and to be captured in corresponding safety case reports.

IAEA Document NS-G-1.6

4.9 ...it should be understood that a high level of analytical sophistication still requires a number of assumptions to be made and produces at best only an indication of seismic behaviour. Data from testing or experience should always be used to validate analytical results, particularly with regard to functionality.

6.3 Low impedance (dynamic characteristic) tests should be limited to identify similarity or to verify analytical models.

6.8 In case low impedance (dynamic characteristic) tests are carried out on items in situ, items are typically tested by means of mechanical actuation,impact, blast and other low energy exciters as well as ambient excitation. These tests should not be used for direct seismic qualification of the item but can be used to define dynamic characteristics, including support, which can then be used in analysis or in other tests to qualify the item of interest.

6.10 ..On-site testing of equipment and components.....represents a reliable strategy for the evaluation of real support, boundary conditions and ageing effects. On-site testing of structures is often the only means of capturing the actual properties of materials, global structural seismic behaviour...

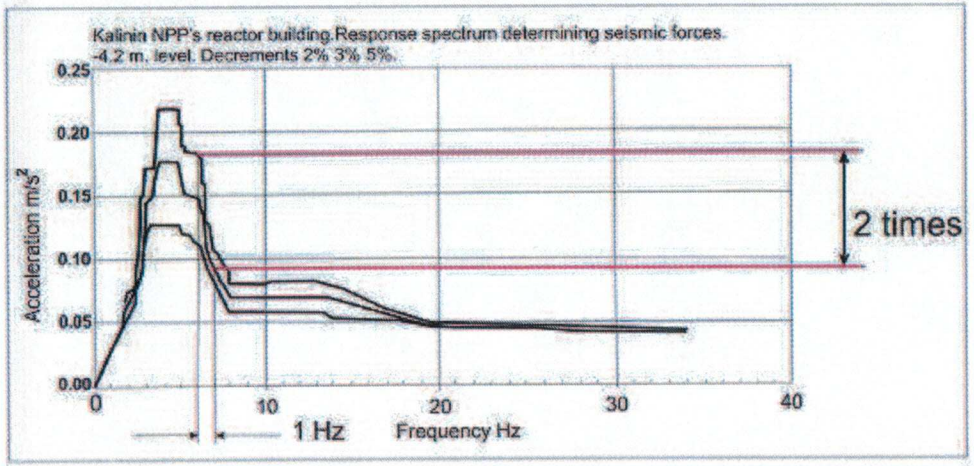
Problem definition

Calculations at the stage of design can not take into account the following factors:

Interaction with every interrelated unit, supports, piping arrangement, heat insulation manufacturing tolerances in rotating and sliding elements.

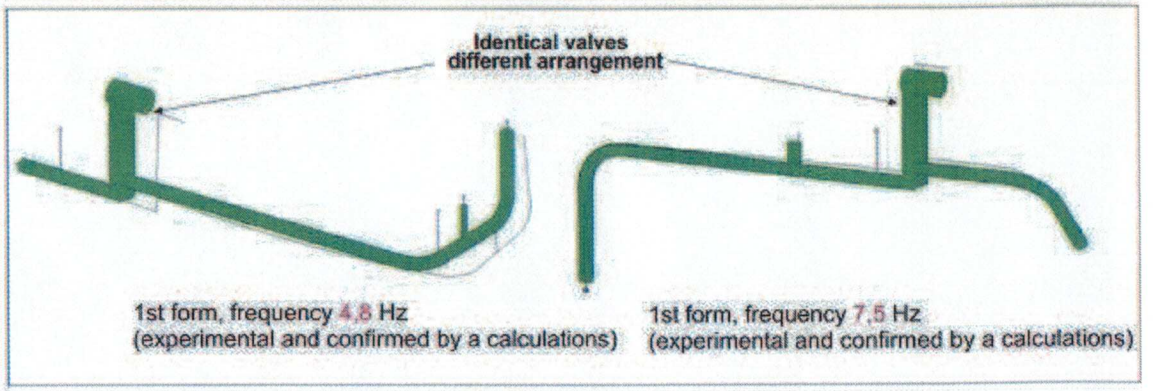
1 Hz deviation of own frequency evaluation can result in mistake of seismic force evaluation up to several times

1% deviation in decrement evaluation can result in mistake of seismic force evaluation up to 2 times



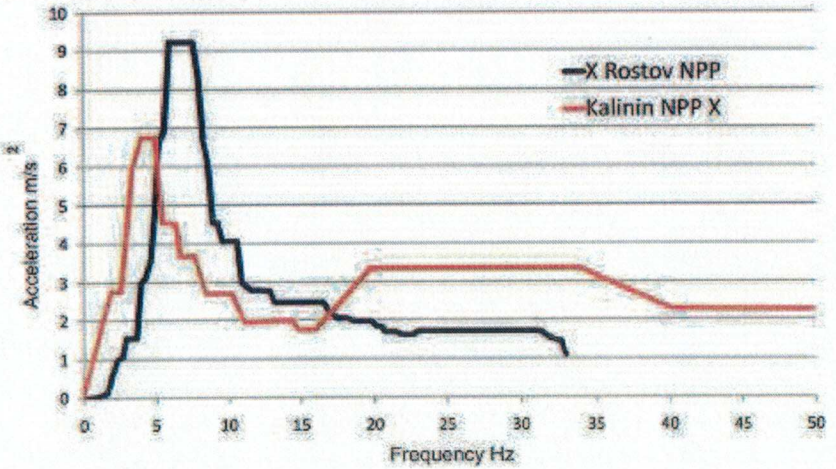
Identical units - Different own frequencies and forms

Our many year's experience shows the huge difference between experimental data and design own frequencies calculations. An error's value can reach a hundreds of percents.
In some cases a number of pipe installation issues are considered during a mounting process.



Different configurations of load spectrums for different NPP's

Diesel generating standby electric power station. Altitude 4.8 m, filling fuel tank.



Consequence:

A transferring of seismic stability analysis results from NPP's power block to another one is absolutely incorrect and unacceptable !!!

Only element-by-element investigation in "as-is" conditions including experimental and computational stage can provide a safety of equipment.

Methods offering to use a universal spectrums of seismic loads with decrements value of 5% (IAEA-TECDOC-1333, Safety Reports Series N28) are also unacceptable.

An inspections of many NPP"s power blocks had shown, that in the number of cases a real values are lower than 2%. Although, this values increase no more than 1,5-2 times under the loading comparable with a real earthquake. Thus, using of decrement's value of 5 % can result in undervaluation of seismic loads.

General steps of seismic safety evaluation

Element-by-element testing

1) Design documentation researching
2) A small oscillations excitation by a slight impact action in three (or more if needed) different directions
3) Recording of digitized movement parameters registered by a sensor (acceleration or velocity)
4) Processing of experimental data by special software with a fast Fourier transform, interpretation of obtained amplitude-response curve

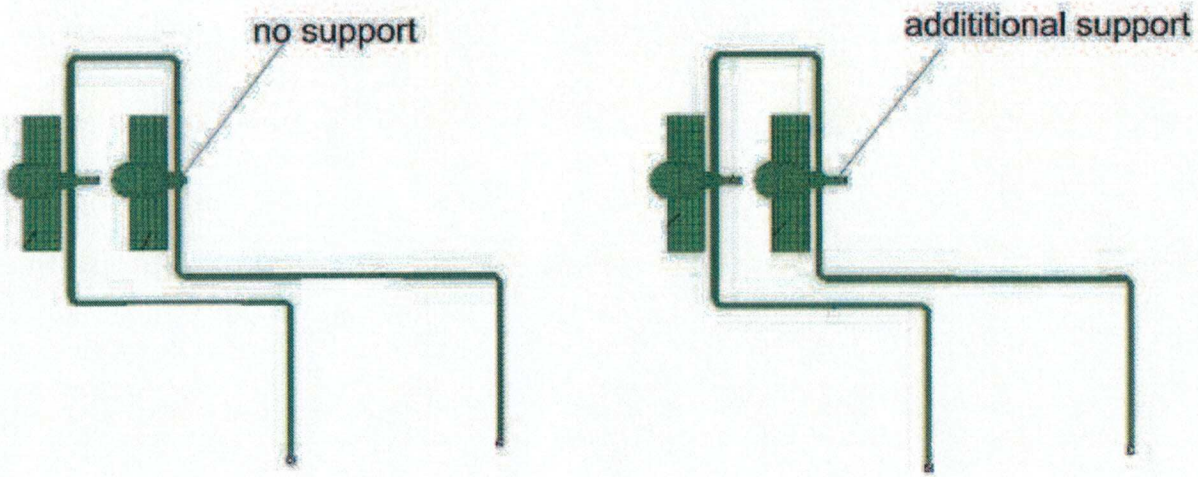
Strength calculations

1) Choosing the most dangerous unit from a number of similar units. The most dangerous unit should have the worst combination of experimental first own frequencies towards resonance peaks on response spectrums
2) Analytic model creation
3) Correcting an analytical model of the object taking the experimental data (obtained own frequencies and forms) into account
4) Strength calculation using different criteria
5) A development of a seismic stability providing measures for unstable units

An implementation of developed seismic stability providing measures

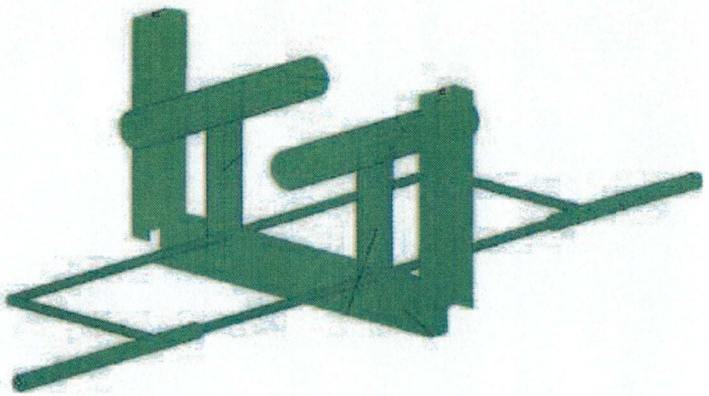
As a rule, all measures are related with a supporting constructions reinforcement

Example of the recommendations for unstable unit



Examples of FE models

valve



absorption trap