18th International Conference on Structural Mechanics in Reactor Technology (SMiRT 18)
Beijing, China, August 7-12, 2005
SMiRT18-K14-2

SEISMIC QUALIFICATION OF DISTRIBUTION BOARD FOR KOZLODUY NPP, UNITS 5&6, BY ANALYTICAL METHOD AND BY ANALOGY

Stanislav Georgiev*
EQE Bulgaria AD
1 H. Smirnenski blvd.
1164 Sofia, Bulgaria
Phone: (+359 2) 9632049
Fax: (+359 2) 9631976
E-mail: skg@eqe.bg

Marin Jordanov
EQE Bulgaria AD
1 H. Smirnenski blvd.
1164 Sofia, Bulgaria
Phone: (+359 2) 9632049
Fax: (+359 2) 9631976
E-mail: mjj@eqe.bg

Ognyan Ganchev
University of Architecture, Civil Engineering and Geodesy,
1 *H. Smirnenski blvd., 1164 Sofia, Bulgaria*
Phone(+359 2) 9635245/384
E-mail: ganchev_fce@uacg.bg

ABSTRACT

This abstract presents the basic approach for seismic qualification by analysis of a distribution board for fire dampers control at Kozloduy NPP WWER-1000MW Reactor Buildings - Units 5&6.

The distribution board is a steel cabinet with mounting plate inside it on which are mounted all the components. For this qualification are used results from preliminary tested on uniaxial seismic platform distribution board with smaller dimensions, but with the same components mounted in it. The smaller board passed successfully the seismic tests and stayed functional after the seismic excitation specified with the prescribed Required Response Spectra (RRS). The seismic qualification by analytical method of the distribution board begins with an overview of the input data used for the analysis, including the RRS and Test Response Spectra (TRS) of preliminary tested distribution board with smaller dimensions. Detailed 3D computer model of the preliminary tested board and comparison between the test results and the results derived by analytical methods are done. For getting more precise modelling, very detailed evaluation of the components (material, mass, location, way of fixture etc.) is made. The mesh of shell and frame elements is suitably selected to describe the behaviour of the board during the seismic tests. Way of fixing of the tested board to the seismic platform is evaluated and properly modelled. Calculated damping for registered by test resonance frequencies of the board is used for adjusting the modal damping in the model. The acceleration time history registered on the seismic platform for selected seismic level is used as an input excitation for the model of the tested board. Calibration of the modelled and the tested distribution board is done by comparison of the generated TRS for given direction of excitation, for selected points at height of the tested board for given damping from one side and Response Spectra (RS) for the same direction of excitation, the same points at height of the modelled board for the same damping on the other side. The compared spectra are similar, which means that the results derived from computer model are close to results from the tested specimen. A 3D computer model of the board to be analytically qualified is made using the calibration results of the model of already tested distribution board. The RS for given direction of excitation and given damping are generated for points of the analytically qualified board proportionally located to the points for which the TRS for the same direction of excitation and damping are generated. The RS should be enveloped by the TRS in order to be concluded, that the analytically tested distribution board can bear the seismic excitation specified by RRS and will stay functional after it. The RS for this specific analytically tested distribution board were not enveloped by the TRS for the tested board and an upgrade of the board was recommended. After the prescribed upgrade and modelling of the upgraded distribution board, was shown that the RS for the three directions of excitation are enveloped by the TRS. Conclusions about the functionality of the distribution board were made also.

Keywords: Seismic qualification by analysis, Distribution board, Required Response Spectra, seismic upgrade, model, damping

1. INTRODUCTION

This paper presents seismic qualification by analysis of a distribution board for fire dampers control in Unit 5 of Kozloduy NPP WWER-1000MW Reactor Building. The purpose of the seismic qualification is to approve the seismic stability and functionality of the distribution board with dimensions 1000/800/300 mm before and after an earthquake defined as Required Response Spectra (RRS). For this seismic qualification are used results from preliminary tested on seismic platform distribution board with smaller dimensions 800/600/250 mm, but with the same components mounted in it. This board has passed the shaking table test successfully and can perform its functions before and after an earthquake. The Test Response Spectra (TRS) for this board defines the RRS for the board to be seismically qualified by analytical method and by analogy [12].

In this paper are presented an overview of the input data used for the analysis, including the RRS and TRS of preliminary tested distribution board; detailed modelling of the tested board and comparison between the test results and the results derived by analytical methods; detailed modelling of the distribution board to be seismically qualified and analyses of the results; recommendations for upgrading of the mounting plate of the distribution board to be seismically qualified and analyses of the results for the upgraded board; conclusions about the functionality of the distribution board.

2. DESCRIPTION OF THE DISTRIBUTION BOARD TO BE SEISMICALLY QUALIFIED – STRUCTURE AND FUNCTION

The distribution board (DB) to be seismically qualified by analytical methods should be mounted in Unit 5 of Kozloduy NPP WWER-1000MW. It has outside dimensions 1000/800/300 mm. The mounting plate is made of steel and has dimensions 955/739 mm. Its thickness is 3 mm and is attached to the back side of the board by 5 bolts (three bolts downside and two bolts upside). The thickness of the door is 2 mm and the enclosure is 1.5 mm thick, also made of steel. The mounting rail, the cable retainer and the PVC cable guides are attached to the mounting plate by self-tapping screws at minimum three points. The distribution board attaches to the wall by four anchor bolts at the angles of the back side.

For comparison the outside dimensions of the tested distribution board are 800/600/250 mm and its mounting plate has dimensions 770/549 mm and it is attached to the back side of the board by 4 bolts (two bolts downside and two bolts upside). The other characteristics are like these of the larger board to be seismically qualified by analytical method.

The function of the distribution board to be seismically qualified is to control the fire dampers mounted in ventilation ducts and compartments situated in Kozloduy NPP Reactor Building, Turbine Hall and Auxiliary Building.

The fire dampers control is intended to provide:

- Automatic closure of a group of fire dampers for each fire zone;
- Manual remote close/open operation of a group of fire dampers;
- Light indication for damper positions;
- Automatic shut-down of the ventilation systems servicing the respective fire zone.

3. EVALUATION CRITERIA FOR FUNCTIONALITY OF DISTRIBUTION BOARD TO BE SEISMICALLY QUALIFIED AND SEISMIC EXCITATION DATA

The main criteria for evaluation of the distribution board are necessity of seismic stability and functionality of its components. The criteria for evaluation of functionality of the distribution board components are developed as follows: Comparison between the TRS derived in selected location points of the mounting plate of smaller distribution board (800/600/250 mm) through the shaking table test and the response spectra derived in the same points of location from the analytical model. As the test results [2] show that the smaller distribution board passed the seismic qualification test successfully, so it is necessary the TRS for the selected location points to envelope the response spectra derived in the same points of location from the analytical model. It should be pointed that this comparison is made at one and the same input excitation for the analytical model and the shaking table test. The shaking table tests are made in accordance with seismic test specification and relevant standards and codes [3], [4], [5], [6], [7], [8] applicable for Nuclear Power Plants (NPP).

The seismic qualification tests of the smaller distribution board are performed separately for each of the three components of the seismic excitation in X, Y and Z direction. Direction X is perpendicular to the mounting plate of the board, direction Y is along its length, and direction Z is vertical. The tests are made for two levels of excitation: Safe Shutdown Earthquake (SSE - high level, SSE = Review Level Earthquake (RLE)) and Operational Basis Earthquake (OBE - low level). The board is tested consequently 5 times with low and ones with high seismic excitation level in each of the three directions. In this manner the seismic aging is simulated as per requirements of the applicable standard [3], [7]. Artificially generated acceleration time histories applied as seismic excitation to the shaking table are derived from RRS for SSE and OBE. RRS is specified by the Client and is presented as a seismic qualification requirement by the producer of the distribution board, ELIA PLC [1]. The RRS for horizontal and vertical components of seismic excitation are identical. Seismic motions of the shaking table are recorded with an accelerometer during test and the corresponding TRS is generated. It should envelope the RRS.

Before the OBE and SSE excitations, resonance tests are made to the distribution board. From these resonance tests can be seen that the mounting plate have resonance frequencies in X direction of excitation (perpendicular to the plane of mounting plate of the board) above 15 Hz and in Y direction of excitation (along the plane of mounting plate) above 25 Hz [2]. Resonance frequencies in Z direction of excitation are greater than 50 Hz (resonance frequencies above 33 Hz are not interesting form structural point of view) and that is why the results for Z direction excitation are not presented below.

On Fig. 1 and Fig. 2 are shown pictures with the location points of accelerometers mounted on the mounting plate of the tested distribution board, respectively at X direction of excitation and Y direction of excitation. On Fig. 3 and Fig. 4 below are shown TRS in logarithmic scale (channel 0 – accelerometer mounted on the seismic platform) and response spectra at location points (channel 1 and channel 2 – accelerometers mounted on the mounting plate), respectively at X direction of excitation and Y direction of excitation. TRS and response spectra presented below are generated for OBE seismic excitation level, selected as representative for the analysis. There is no significance which one of the SSE or OBE excitation levels are taken as representative for the analysis, because at SSE excitation level the results are only multiplied twice. So, for the analytical analysis of the distribution board are taken test results for one of the five OBE excitation levels. TRS and response spectra are calculated for 4% damping, as well as the RRS specified by the Client. From the diagrams below it can be seen that TRS envelopes RRS at frequencies higher than 3 Hz, which is admissible according to [3], [7] if first resonance frequency is higher than 5 Hz.

Figure 1
Accelerometers location on tested distribution board – X direction of excitation

Figure 2
Accelerometers location on tested distribution board – Y direction of excitation

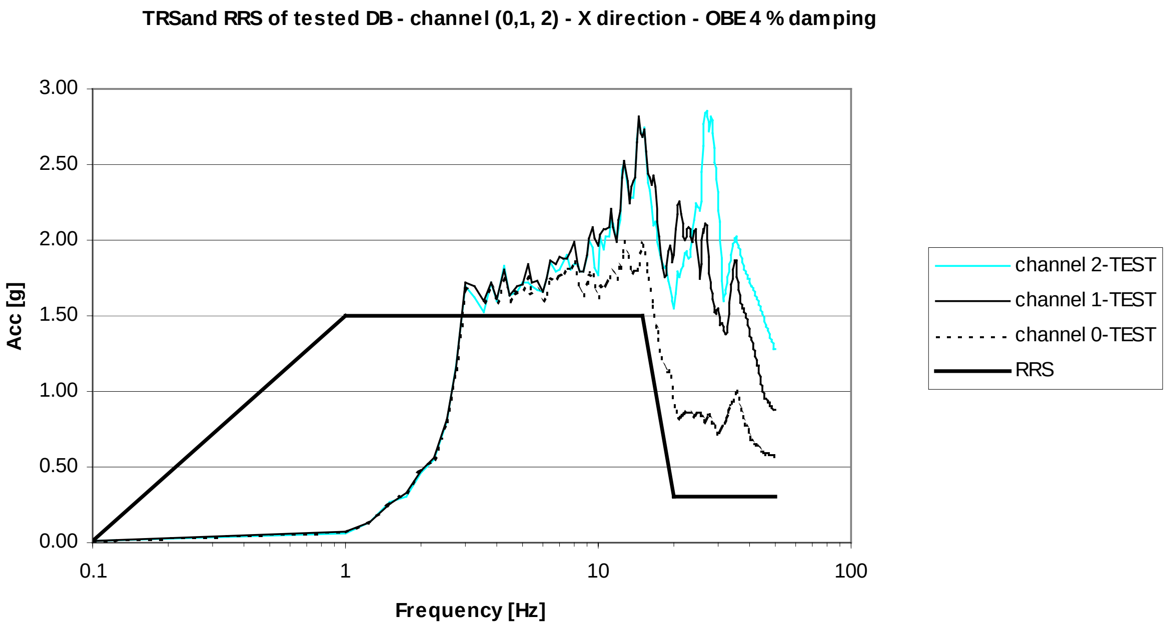

Figure 3 *Diagram of RRS, TRS and response spectra at selected location points of the tested distribution board – X direction of excitation*

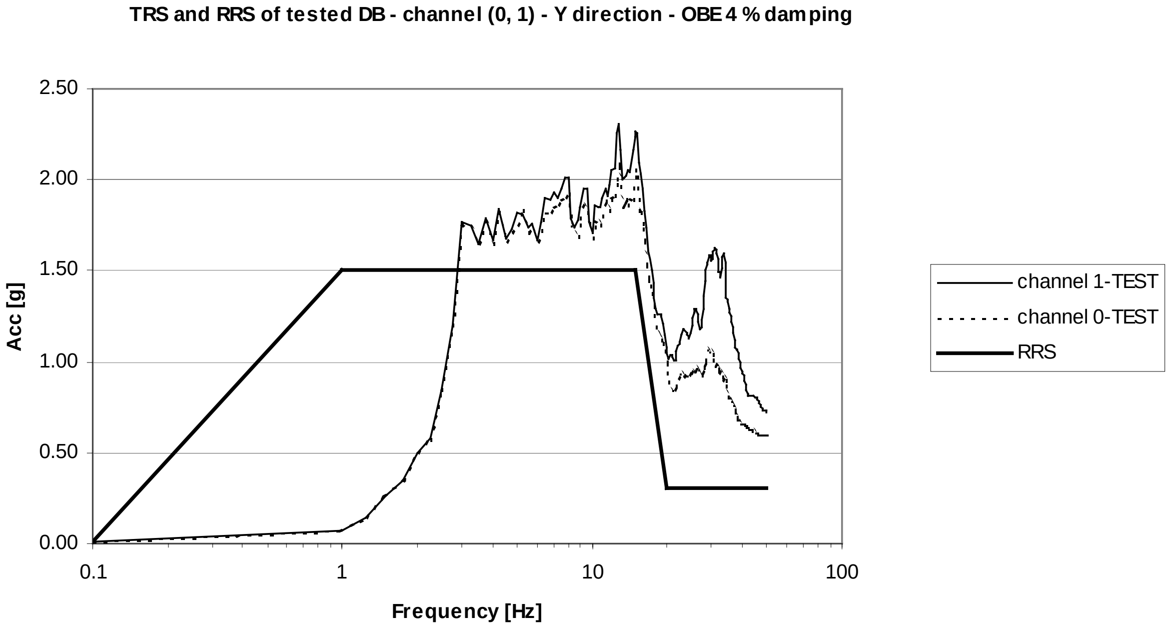

Figure 4 Diagram of RRS, TRS and response spectra at selected location points of the tested distribution board – Y direction of excitation

4. SEISMIC QUALIFICATION WITH ANALYTICAL METHODS (MODELLING) OF DISTRIBUTION BOARD BY USING RESULTS OF TESTED BOARD

For structural modelling and dynamic analysis of distribution board a 3-D computer model is made, using the computer program SAP2000 [9]. This computer program is developed for static and dynamic analyses of 3-D structures using the Finite Elements Method (FEM). 3-D frame and shell elements were used. The models have been developed, utilizing the available documentation given by the Client [1]. Models are based on measured board and component dimensions, geometry and material properties of components in the studied structure. 3-D frame elements were used basically to model mounting rails, PVC cable guides, cable retainers and bolts and the cross-sections geometry properties of the model frame elements are equivalent to the geometry properties of the existing elements cross-sections. A mesh of shell elements with similar width and height dimensions is used to model the steel sides shielding of the distribution board, its door and mounting plate. Shell thickness equals the thickness of the existing steel sheet of the analysed distribution board. Relays, breakers, terminals and wires are taken into account as concentrated masses at the model joints of mounting rails. Lamps are taken into account as concentrated masses at the door model joints. Mass of relays, breakers, terminals, wires and lamps is given in [1] and the external cables have mass 200 grams/meter/cable. Both steel and PVC materials are used in the analytical model and their mechanical properties are:

- The modulus of elasticity of steel is E=206 000 MPa and E=3 000 MPa of PVC;
- The weight of steel is w=78.50kN/m^3 and w=6.00kN/m^3 of PVC

The static and dynamic analyses were conducted using [9], based on the above assumptions. Natural frequencies were obtained by Eigen frequency analyses for evaluation of the dynamic characteristics of the models. A Ritz-vector analyses [9] were performed for calculation of base reactions in anchoring bolts.

Only elastic behaviour was considered when the seismic demand of anchorage elements was estimated [10]. A loading combination of dead load and seismic excitation has been analysed according to [10], [11], [12]. The applicable load combination equation for the elastic state is:

D + Ess

where: D - dead loads

Ess - load effects of safe shutdown earthquake (SSE) = 2*(OBE)

The analysis of the anchorage is made for this load combination.

4.1 Model of tested distribution board

A 3-D computer model of the tested distribution board is made first, in order to calibrate the results derived from test and these derived from the analytical model. The model is made in accordance with assumptions described in above. Total mass of DB is 47 kg without external cables. The boundary conditions in the model of tested DB are four fixed joints (distance between them is 560 mm in horizontal and 760 mm in vertical direction). General view of the model of the distribution board and the mounting plate inside it can be seen on Fig. 5 below. Dimensions of DB are 800/600/250 mm. Note that direction X in the SAP 2000 model is perpendicular to the plane of mounting plate, while direction Y is along it. Direction Z is vertical.

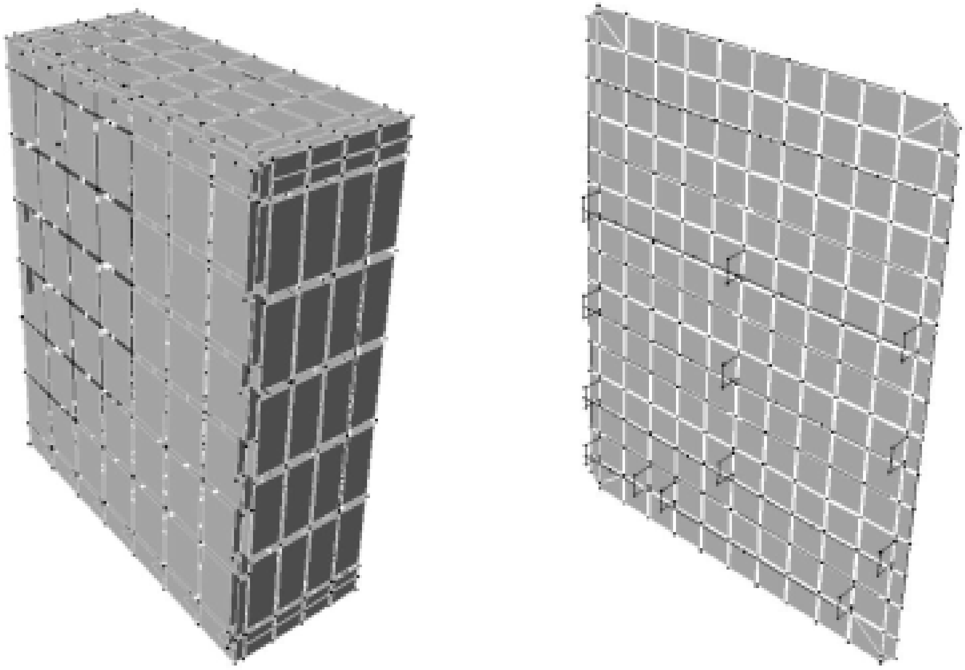

Figure 5 General view of the model of tested DB (distribution board and mounting plate)

Seismic analysis is performed using the acceleration time history recorded on the seismic platform (55 sec duration), during test with OBE excitation (channel 0), as an input excitation in the model. The analysis is performed with 1 component seismic motion, separately for X and Y direction of excitation.
In Table 1 below are given the natural frequencies and modes, as well as the modal participating mass ratios for the model of the tested distribution board
Natural frequencies and modes are obtained by the of Eigenvector analysis [9]. The natural frequencies up to 50 Hz are presented in the table below.

Table 1 Natural frequencies, modes and modal participating mass ratios of tested DB

Mode	Period	Frequency	Modal participating mass ratios			Sum		
	s	Hz	UX	UY	UZ	UX	UY	UZ
1	2	3	4	5	6	7	8	9
1	0.059	16.998	17.773	0.000	0.000	17.773	0.000	0.000
2	0.044	22.657	19.338	0.000	0.000	37.111	0.000	0.000
3	0.043	23.273	25.295	0.000	0.001	62.406	0.000	0.001
4	0.030	33.702	0.001	0.000	0.049	62.407	0.000	0.050
5	0.027	37.276	0.148	0.000	2.558	62.556	0.000	2.607
6	0.025	40.336	0.024	0.000	0.001	62.580	0.000	2.608
7	0.022	44.679	0.039	0.176	0.016	62.619	0.176	2.624
8	0.022	46.209	0.000	0.062	0.000	62.620	0.238	2.624
9	0.019	53.183	0.000	0.938	0.000	62.620	1.176	2.624

The first two modes with largest mass participation mass ratios are presented on Figures 6 and 7 below.

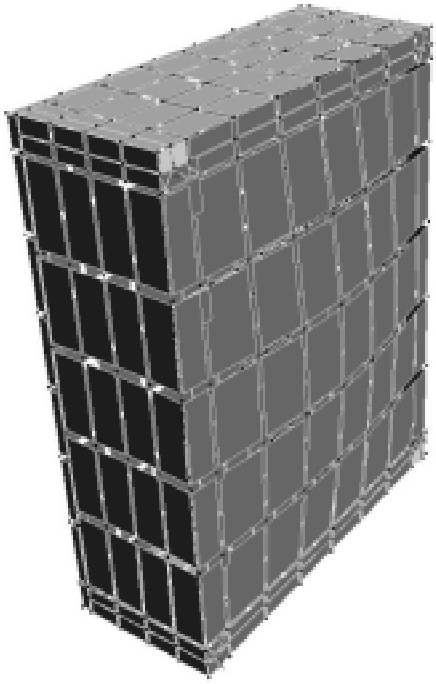

Figure 6
2-nd mode of the model of tested board (back side response)

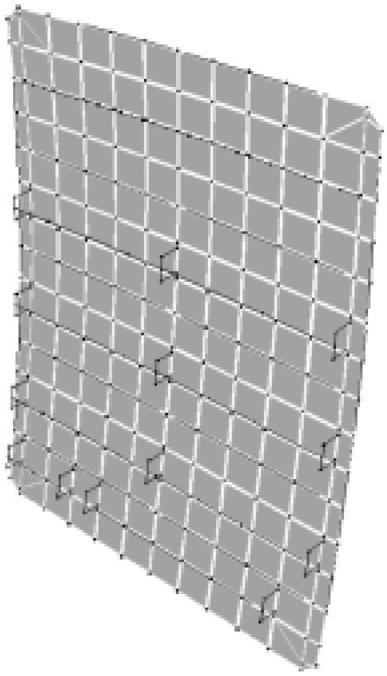

Figure 7
3-rd mode of the model of tested board (mounting plate response)

The response spectra derived from test at selected location points of the mounting plate are compared to the results derived from the analytical model for the same location points. This comparison is made for OBE excitation at X and Y direction. On Figures 8 and 9 are presented the diagrams showing the response spectra from test and analytical model in X direction of excitation, respectively for channel 1 and channel 2. On Fig. 10 is presented the diagram showing the response spectra from test and analytical model in Y direction of excitation - channel 1. On the figures TRS (channel 0) is also shown.
From the comparison can be seen that results from test and analytical model are similar.

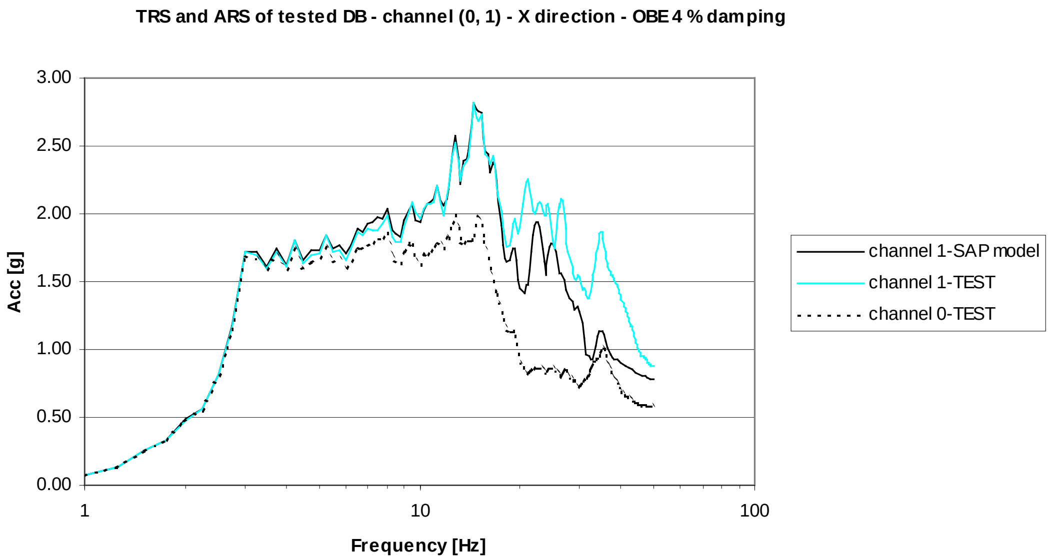

Figure 8 *– X direction (channel 1)*

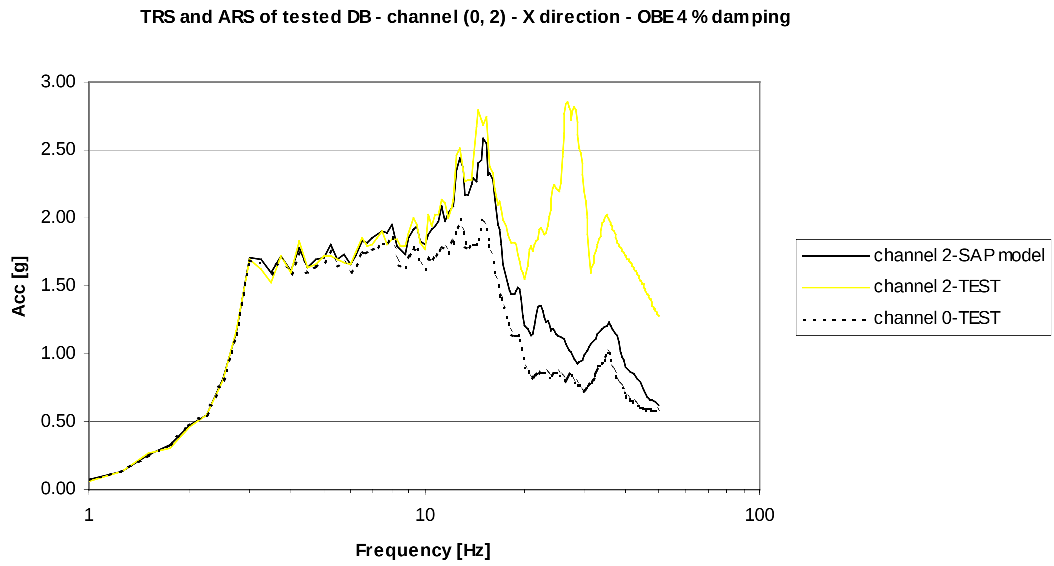

Figure 9 Response spectra of DB from test and analytical model – X direction (channel 2)

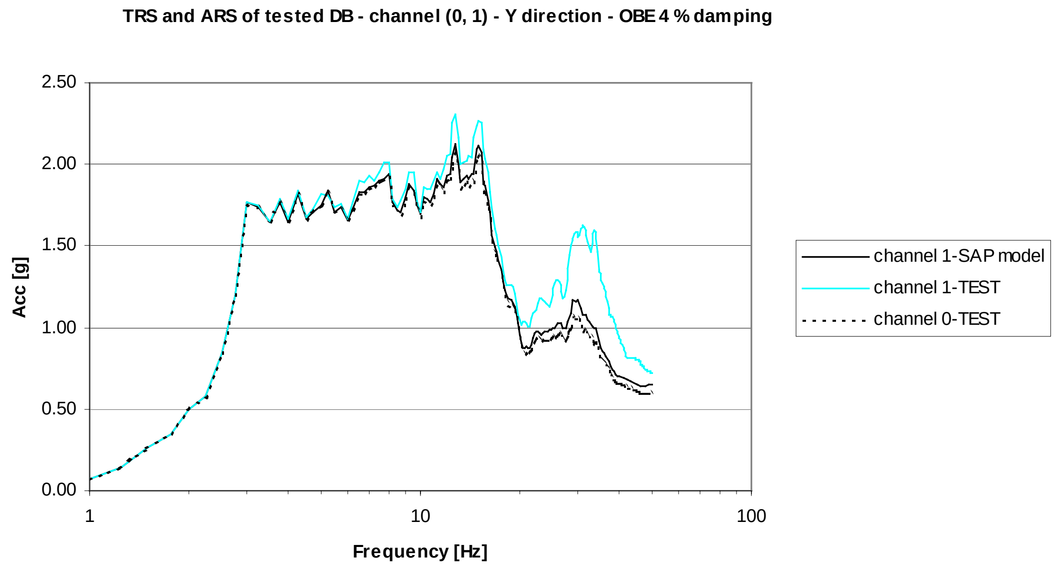

Figure 10 Response spectra of DB from test and analytical mode l– Y direction (channel 1)

4.2 Model of distribution board to be seismically qualified

A 3-D computer model of the distribution board to be seismically qualified is made using the characteristics of the elements of the tested DB, as results derived from test and these derived from the analytical model are similar. The model is made in accordance with assumptions described in above. Total mass of DB is 70 kg without external cables. The boundary conditions in the model of DB are four fixed joints (distance between them is 760 mm in horizontal and 960 mm in vertical direction). General view of the model of the distribution board to be seismically qualified and the mounting plate inside it can be seen on Fig. 11 below. Dimensions of DB are 1000/800/300 mm. Note that direction X in the SAP 2000 model is perpendicular to the plane of mounting plate, while direction Y is along it. Direction Z is vertical.

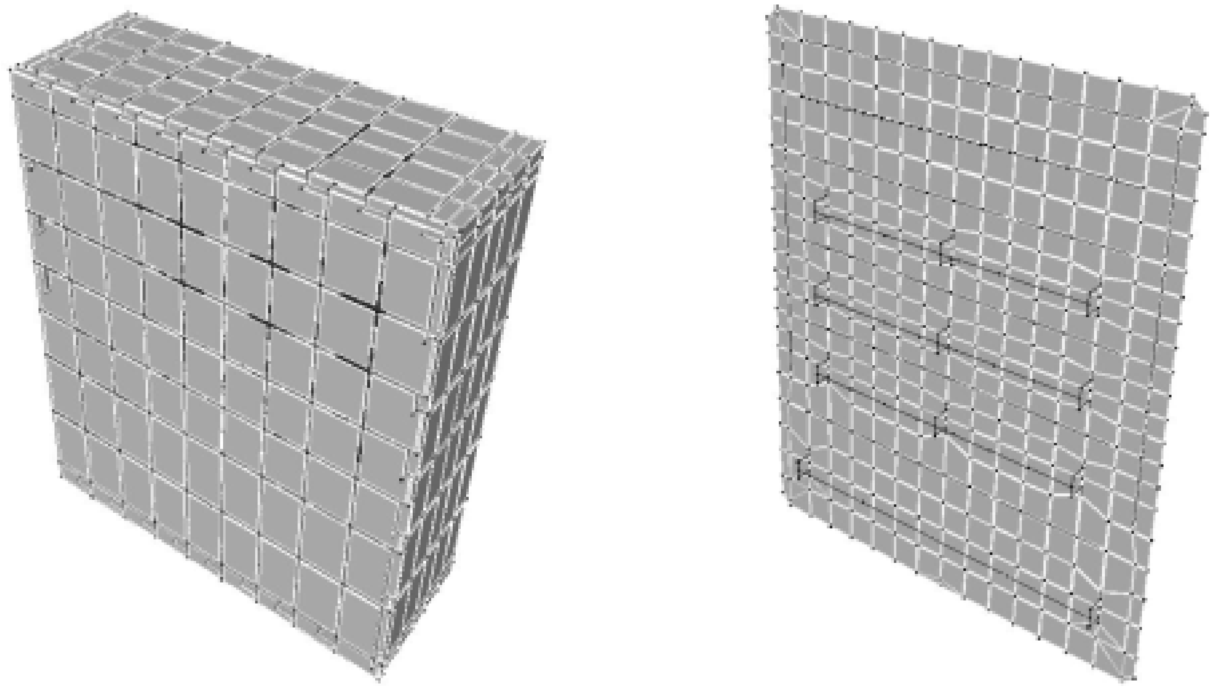

Figure 11 General view of the model of DB to be seismically qualified (distribution board and mounting plate)

Seismic analysis is performed using the acceleration time history recorded on the seismic platform (55 sec duration), during test with OBE excitation (channel 0), as an input excitation in the model. The analysis is performed with 1 component seismic motion, separately for X and Y direction of excitation.
In Table 2 below are given the natural frequencies and modes, as well as the modal participating mass ratios for the model of the distribution board to be seismically qualified.
Natural frequencies and modes are obtained by the of Eigenvector analysis [9]. The natural frequencies up to 50 Hz are presented in the table below.

Table 2 Natural frequencies, modes and modal participating mass ratios of DB to be seismically qualified

Mode	Period	Frequency	Modal participating mass ratios			Sum		
	s	Hz	UX	UY	UZ	UX	UY	UZ
1	2	3	4	5	6	7	8	9
1	0.099	10.115	17.592	0.000	0.000	17.592	0.000	0.000
2	0.072	13.818	15.517	0.000	0.007	33.109	0.000	0.007
3	0.067	15.002	25.487	0.000	0.079	58.596	0.000	0.086
4	0.046	21.535	0.032	0.000	0.004	58.627	0.000	0.089
5	0.039	25.868	0.264	0.000	0.341	58.891	0.000	0.430
6	0.036	27.991	0.094	0.048	0.006	58.985	0.048	0.436
7	0.036	28.138	0.435	0.002	0.031	59.419	0.050	0.467
8	0.034	29.301	2.759	0.009	0.277	62.178	0.059	0.745
9	0.032	31.071	0.000	0.518	0.000	62.178	0.578	0.745
10	0.027	36.378	3.043	0.000	0.000	65.221	0.578	0.745
11	0.024	42.068	0.000	0.002	0.000	65.221	0.580	0.745
12	0.024	42.210	0.000	0.001	0.000	65.221	0.581	0.745
13	0.023	43.674	1.525	0.000	0.177	66.746	0.581	0.921
14	0.020	48.905	0.094	0.000	0.180	66.840	0.581	1.101
15	0.020	49.988	0.117	0.000	0.037	66.957	0.581	1.138
16	0.019	51.451	0.502	0.038	5.850	67.459	0.619	6.988

The first two modes with largest mass participation mass ratios are presented on Figures 12 and 13 below.

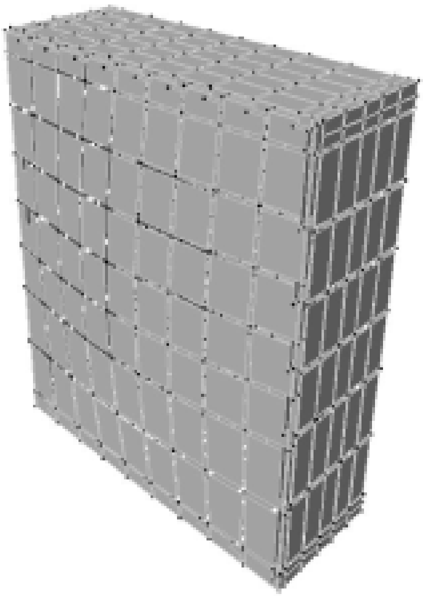

Figure 12
1-st mode of the model of board to be seismically qualified (door response)

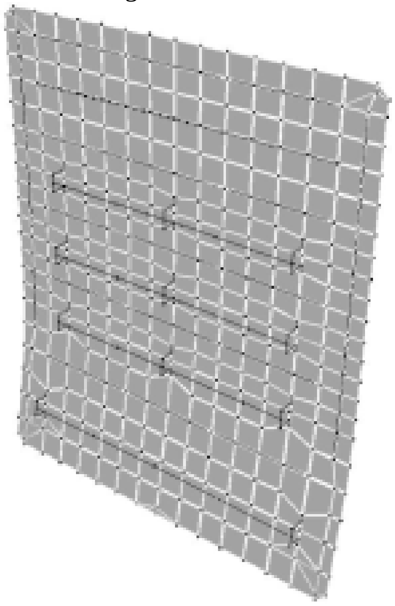

Figure 13
3-rd mode of the model of board to be seismically qualified (plate response)

The response spectra derived from test at selected location points of the mounting plate are compared to the results derived from the analytical model for the same location points. This comparison is made for OBE excitation at X direction only. On Figures 14 and 15 are presented the diagrams showing the response spectra from test and analytical model in X direction of excitation, respectively for channel 1 and channel 2. On the figures TRS (channel 0) is also shown. The response spectra generated from test for the selected location points should envelope response spectra for the same location points generated from the analytical model. This is the criterion, which should be fulfilled so that the distribution board to be seismically qualified.
From the comparison of the response spectra presented on the diagrams below, can be seen that response spectra for channels 1 and 2 from the analytical model are not enveloped, by these for channels 1 and 2 respectively generated by test. This means that an upgrade of the mounting plate is necessary. In subsection 4.3 below is described this upgrading.

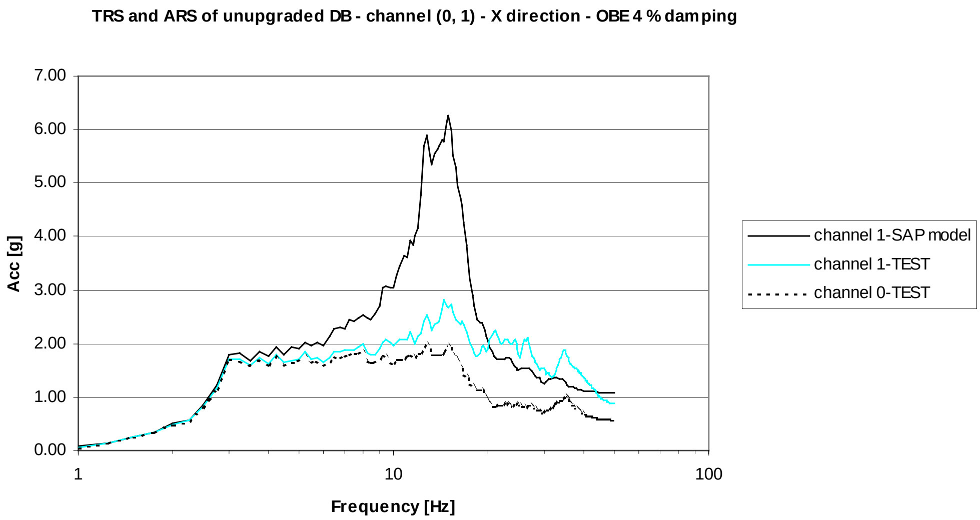

Figure 14 Response spectra of DB from test and analytical model – X direction (channel 1)

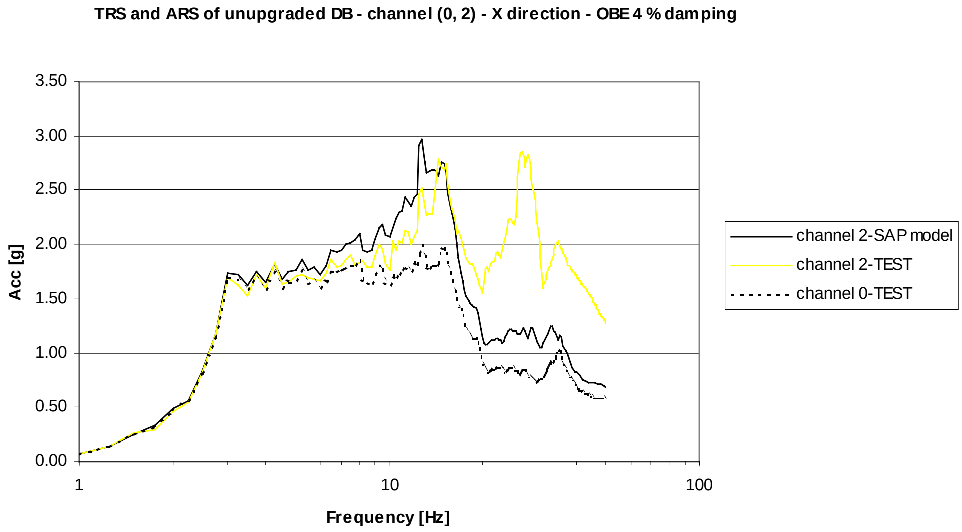

Figure 15 Response spectra of DB from test and analytical model – X direction (channel 2)

4.3 Model of upgraded distribution board to be seismically qualified

A 3-D computer model of the upgraded distribution board to be seismically qualified is made using the model of the unupgraded distribution board. The very upgrading is: strengthening of the mounting plate from its back side with three vertical (two at the ends and one in the middle) and two horizontal (in the upper and down side of the plate) steel square hollow sections with dimensions 25/25/2 mm. The attachment of the sections to the mounting plate becomes by blind rivets. The model is made in accordance with assumptions described above. The boundary conditions in the model of upgraded DB are four fixed joints (distance between them is like that of unupgraded DB). General view of the model of the distribution board to be seismically qualified and the upgraded mounting plate inside it can be seen on Fig. 16 below. Dimensions of distribution board are the same – 1000/800/300 mm. Note that direction X in the SAP 2000 model is perpendicular to the plane of mounting plate, while direction Y is along it. Direction Z is vertical.

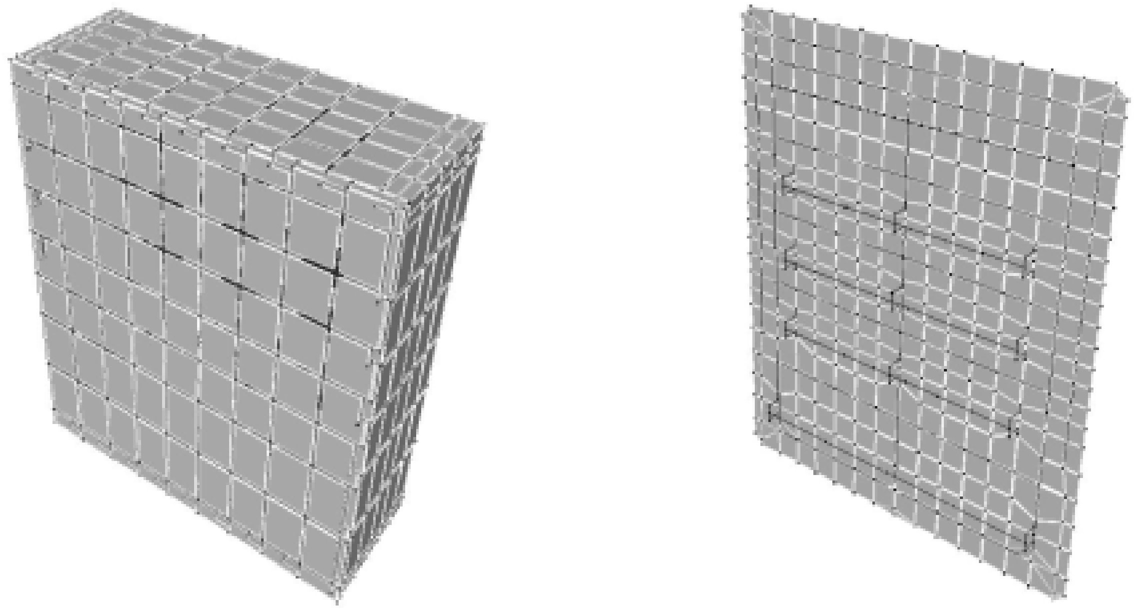

Figure 16 General view of the model of upgraded DB to be seismically qualified (distribution board and mounting plate)

Seismic analysis is performed using the acceleration time history recorded on the seismic platform (55 sec duration), during test with OBE excitation (channel 0), as an input excitation in the model. The analysis is performed with 1 component seismic motion, separately for X and Y direction of excitation.
In Table 3 below are given the natural frequencies and modes, as well as the modal participating mass ratios for the model of the upgraded distribution board to be seismically qualified.
Natural frequencies and modes are obtained by the of Eigenvector analysis [9]. The natural frequencies up to 50 Hz are presented in the table below.

Table 3 Natural frequencies, modes and modal participating mass ratios of the upgraded DB to be seismically qualified

Mode	Period	Frequency	Modal participating mass ratios			Sum		
	s	Hz	UX	UY	UZ	UX	UY	UZ
1	2	3	4	5	6	7	8	9
1	0.099	10.115	16.451	0.000	0.000	16.451	0.000	0.000
2	0.072	13.865	8.780	0.000	0.000	25.231	0.000	0.000
3	0.046	21.535	0.022	0.000	0.004	25.253	0.000	0.004
4	0.040	24.795	40.503	0.000	0.003	65.756	0.000	0.007
5	0.038	26.067	0.909	0.000	0.170	66.665	0.000	0.177
6	0.036	28.021	0.000	0.027	0.000	66.665	0.027	0.177
7	0.032	31.049	0.001	0.482	0.000	66.666	0.509	0.177
8	0.027	36.382	2.547	0.000	0.000	69.213	0.509	0.177
9	0.025	39.796	0.129	0.358	0.036	69.342	0.867	0.213
10	0.024	42.068	0.000	0.002	0.000	69.342	0.869	0.213
11	0.024	42.221	0.000	0.002	0.000	69.342	0.871	0.213
12	0.023	43.437	0.946	0.011	0.261	70.288	0.883	0.475
13	0.021	47.486	0.114	0.018	1.211	70.402	0.901	1.686
14	0.020	49.010	0.023	0.001	0.609	70.425	0.902	2.295
15	0.020	50.000	0.140	0.000	0.002	70.565	0.902	2.297
16	0.018	54.975	0.001	14.811	0.001	70.566	15.713	2.297

The first two modes with largest mass participation mass ratios are presented on Figures 17 and 18 below.

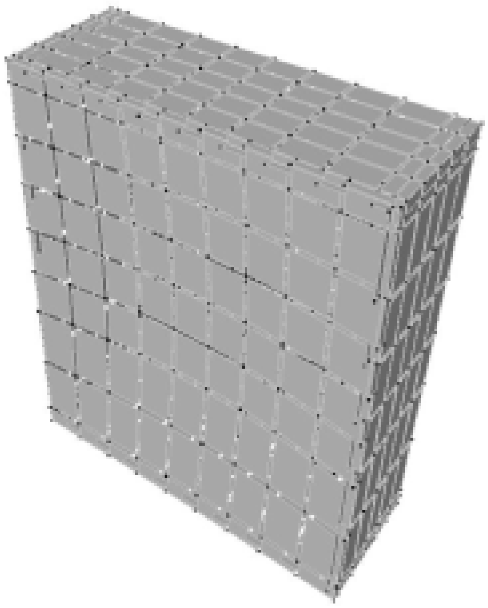

Figure 17
1-st mode of the model of the upgraded board to be seismically qualified (door response)

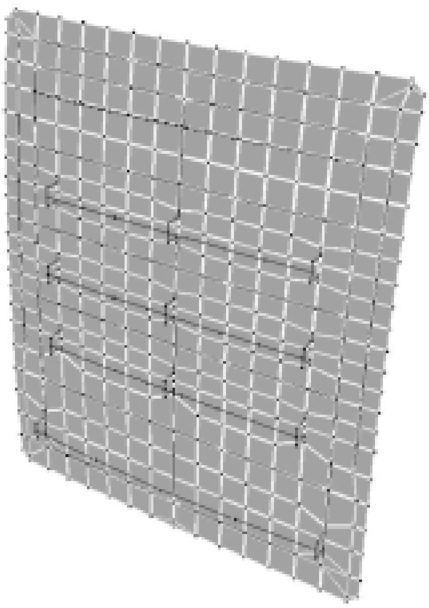

Figure 18
4-th mode of the model of the upgraded board to be seismically qualified (plate response)

The response spectra derived from test at selected location points of the mounting plate are compared to the results derived from the analytical model for the same location points. This comparison is made for OBE excitation at X and Y direction. On Figures 19 and 20 are presented the diagrams showing the response spectra from test and analytical model in X direction of excitation, respectively for channel 1 and channel 2. On Fig. 21 is presented the diagram showing the response spectra from test and analytical model in Y direction of excitation - channel 1.
On the figures TRS (channel 0) is also shown. The response spectra generated from test for the selected location points should envelope response spectra for the same location points generated from the analytical model. This is the criterion which should be fulfilled so that the distribution board to be seismically qualified(to perform its functions before and after an earthquake defined as RRS).
From the comparison of the response spectra presented on the diagrams below, can be seen that response spectra for channels 1 and 2 (X direction of excitation) from the analytical model are enveloped by these for channels 1 and 2, respectively generated by test. Response spectrum for channel 1 (Y direction of excitation) from the analytical model is enveloped by this for channel 1 respectively generated by test. This means that the criterion is fulfilled.

TRS and ARS of upgraded DB - channel (0, 1) - X direction - OBE 4 % damping

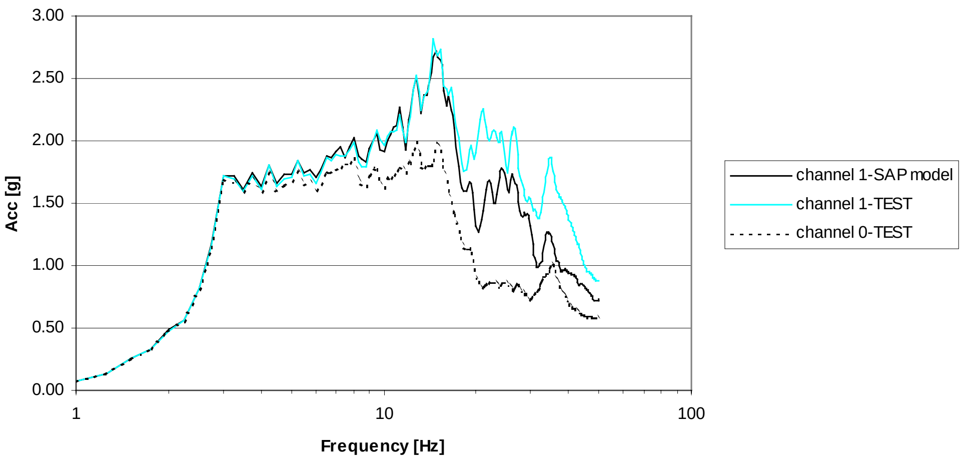

Figure 19 Response spectra of upgraded DB from test and analytical model – X direction (channel 1)

TRS and ARS of upgraded DB - channel (0, 2) - X direction - OBE 4 % damping

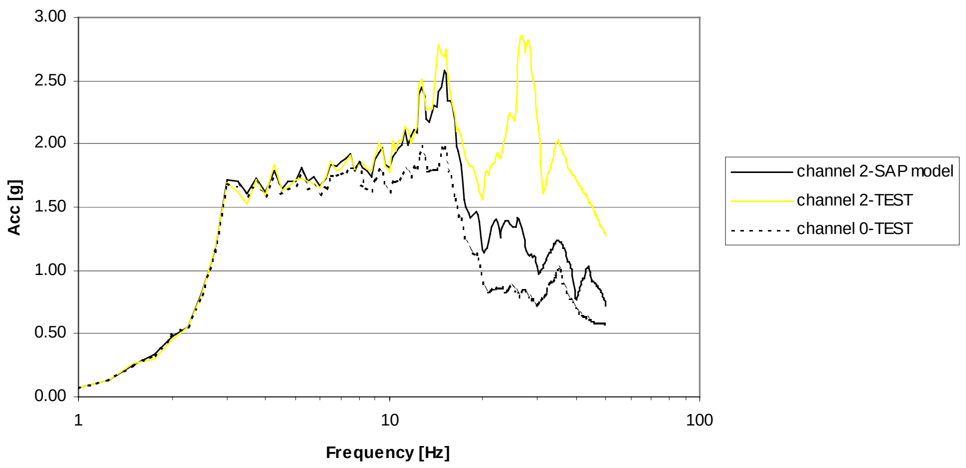

Figure 20 Response spectra of upgraded DB from test and analytical model – X direction (channel 2)

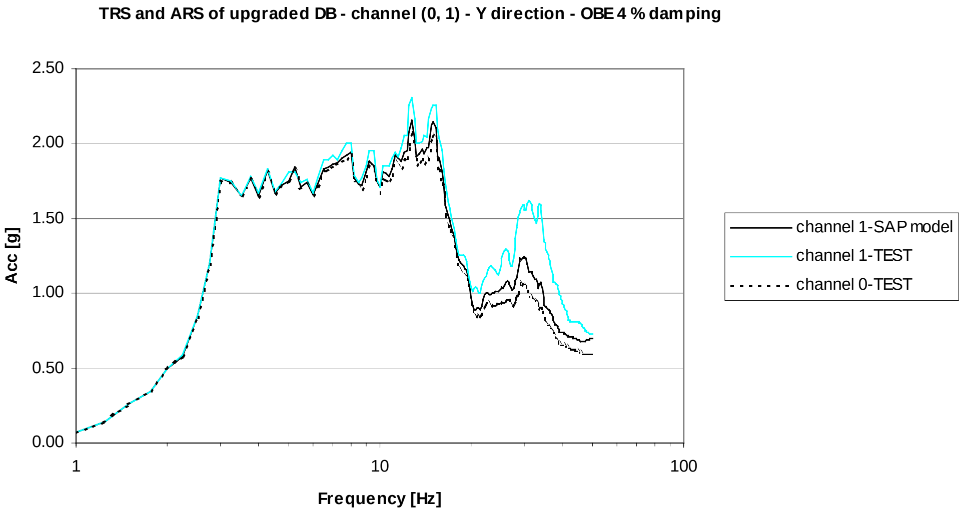

Figure 21 Response spectra of upgraded DB from test and analytical model – Y direction (channel 1)

The selected type of anchor bolts for attaching the distribution board to concrete wall is HILTI. These bolts have bearing capacity according to [13]. The maximum received force in the high loaded anchor bolt by the analytical model of the upgraded distribution board for load combination D + Ess is used for demand-to-capacity check. This check shows that the prescribed anchor bolts can carry the applicable seismic loading and are assessed as reliable.

5. CONCLUSIONS

After carrying out the detailed seismic analysis of the distribution board with dimensions 1000/800/300 mm the following conclusions can be made:

- The equipment is reliably attached to the mounting plate as a whole.
- After the prescribed upgrading of the mounting plate of the distribution board with steel frame of square hollow sections with dimensions 25/25/2 mm on its back side, the response spectra generated from the analytical model for selected points are fully enveloped by the response spectra generated from the test for the same points. This shows that distribution board is seismically qualified and can perform its functions before and after an earthquake defined as RRS.
- The prescribed anchor bolts are verified for the applicable seismic loading and are assessed as reliable.

After execution of the prescribed upgrading it can be concluded that the distribution board is seismically qualified and will stay stable and will perform its functions before and after an earthquake defined as RRS. The equipment mounted on the mounting plate and the door of the distribution board will stay functional and undamaged.

6. REFERENCES

[1] Distribution board technical documentation drawings, ELIA PLC, 2004
[2] Seismic qualification by test of electrical cabinets for fire dampers control, EQE Bulgaria Report EQEB-10305-R-03, Sofia, 2003
[3] IEEE Standard 344-1987, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
[4] IEEE Standard 501-1978 (C37.98), Seismic Testing of Relays
[5] IEEE Standard 420-1982, IEEE Standard for the Design and Qualification of Class 1E Control Boards, Panels and Racks used in Nuclear Power Generating Stations
[6] US Nuclear Regulatory Commission, Regulatory Guide 1.100, Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants

[7] International Standard CEI / IEC 980-1989, Recommended Practice for Seismic Qualification of Electrical Equipment for Nuclear Power Generating Stations, International Electrotechnical Commission (IEC)
[8] IEEE Standard 323, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
[9] SAP 2000, Ver 7.44, Three Dimensional Static and Dynamic Finite Element Analysis and Design of Structures, CSI, Berkeley, California, 2002
[10] Guide for Seismic Reevaluation and Design of Nuclear Facilities in Bulgaria, 2002
[11] AISC N690-1984, Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities, ANSI/AISC N690, 1984
[12] IAEA Safety Guide NS-G-1.6, Seismic Design and Qualification for Nuclear Power Plants, IAEA, 2003
[13] HILTI Fastening Technology Manual, 2002