VIBRATION TESTS ON "IS 2" RACK SYSTEMS

RACK WITH VIBRATION DUMPERS

TEST REPORT

ON BEHALF OF: ABB SPA - ABB SACE DIVISION - MILANO

RT-AB-014/09-a rev. 00

Document of 25 pages

Written: Michele Civera 03/03/2009
Verified and approved: Alessandro Bonzi 05/03/2009
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1. GENERAL DATA

1.1. Customer

ABB S.p.A. – ABB SACE Division
Via Vittor Pisani, 16
20124 Milano (MI)
ITALIA

1.2. Unit under test

Vibration tests on a rack system IS-2 with vibration dumpers. The total mass of the equipment was about 400 kg.

1.3. Reference documents

1.3.1. Contract documents


1.3.2. Documenti tecnici e normative

1. IEC 60068-2-6: Environmental testing - Part 2: Tests - Test Fc: Vibration (sinusoidal)

1.4. Test objective

The purpose of the tests was to demonstrate that, in the requested frequency range, vibration in two internal points are under the threshold of 0,5 g when the excitation level at the base of the rack is 0,1 g.

1.5. Testing laboratory

P&P LMC Srl
Via Pastrengo, 9
24068 SERIATE (BG)
ITALY

1.6. Test date

February, 27th 2009.

1.7. Responsibilities

Alessandro Bonzi, project leader – Michele Civera, test specialist.

1.8. Witnesses

Livio Corbetta        ABB S.p.A.
Ferrari              ABB S.p.A.
2. TESTING PROCEDURES

2.1. General remarks

The tests consisted in:

- Vibration Response Investigation (VRI) tests in three different directions (X, Y, Z)

All the applied vibrations were monodirectional.

The in Z direction were performed on a vertical shaking table moved by an electro-dynamic shaker. For the other excitation directions, a horizontal shaking table was used. Excitation directions are shown in the photographs.

All the performed tests are listed in the tables of page 14.

2.2. Mounting techniques

For the tests the unit was fixed shaking table with No. 5 M12 screws with a tightening torque of 90 Nm.

2.3. Control and measuring positions

During the tests, for the motion control the signal of an accelerometer in the excitation direction (CP1) was used. Moreover, on the unit under test N.3 accelerometers were used to acquire the signal of the vibration in three characteristic points indicated by the customer (see figure and associated table).

<table>
<thead>
<tr>
<th>Measuring positions</th>
<th>Model</th>
<th>Serial number</th>
<th>Calibration document</th>
<th>Test Nr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP1: Control</td>
<td>353A</td>
<td>1374</td>
<td>SIT N. 178/S0037/09</td>
<td>All tests</td>
</tr>
<tr>
<td>MPA: position A</td>
<td>M353B18</td>
<td>71240</td>
<td>SIT N. 178/S0026/09</td>
<td>All tests</td>
</tr>
<tr>
<td>MPB: position B</td>
<td>M353B18</td>
<td>71238</td>
<td>SIT N. 178/S0025/09</td>
<td>All tests</td>
</tr>
<tr>
<td>MPC: position C</td>
<td>M353B18</td>
<td>71241</td>
<td>SIT N. 178/S0027/09</td>
<td>2 ÷ 3</td>
</tr>
</tbody>
</table>

2.4. Sine vibration tests

The specimen was subjected to sinusoidal scannings, with the following dynamic characteristics:

- Frequency range: 10-500 Hz;
- Peak acceleration: 0.1 g (g=9.81 m/s²);
- Sweep rate: 1 oct/min;
- Test duration: 1 sweep for each axis;
- Excitation direction: X; Y; Z.

Signals from measuring accelerometers were processed to obtain the absolute response functions\(^1\) of the control channel and the frequency transfer functions of the measuring channels on the unit.

### 3. MEASURING, EXCITATION AND DATA PROCESSING EQUIPMENT

#### 3.1. Excitation equipment

Vibration tests in vertical direction were carried out using an electro-dynamic shaker manufactured by ELIN, type MZV 210 W 20 with the following characteristics:

- maximum sinusoidal dynamic force: 100 kN;
- moving element weight: 1000 N;
- frequency range: 0 ÷ 2000 Hz;
- max. displacement (peak to peak): 51 mm;
- max. velocity: 2000 mm/s;
- max. acceleration: 98 g.

Vibration tests in horizontal directions were carried out using a magnesium slip table (operated by the previously described ELIN shaker) with the following characteristics:

- maximum sinusoidal dynamic force: 100 kN;
- moving element weight: 3.4 kN;
- frequency range: 0 ÷ 500 Hz;
- max. displacement (peak to peak): 51 mm;
- max. velocity: 2000 mm/s;
- fixing surface: 1100 x 950 mm.

#### 3.2. Measuring equipment

Accelerometers employed during all the tests were PCB 353 A and PCB 353 B18 monoaxial accelerometers with incorporated amplifiers.

The main characteristics of the accelerometers are listed below:

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\(^1\) The absolute response function is the phasor of the response signal, a complex number the magnitude of which is the amplitude of the first harmonic of the oscillation and the angle of which is the phase. The frequency response transfer function is the frequency dependent ratio of the motion-response phasor to the phasor of the excitation motion; this is a complex function and it is given graphically by curves showing the ratio of the first harmonic amplitude of the response signal to the first harmonic amplitude of the excitation signal and the relevant phase shift or phase angle versus the frequency.
**PCB 353 A:**

- Nominal sensitivity: 20 mV/g;
- Transverse sensitivity (max): < 5%;
- Frequency range: 1 ÷ 4000 Hz;
- Max. acceleration: 250 g;
- Resolution: 0.005 g;
- Weight: 0.10 N.

**PCB M353 B18:**

- Nominal sensitivity: 10 mV/g;
- Transverse sensitivity (max): < 5%;
- Frequency range: 1 ÷ 10000 Hz;
- Max. acceleration: 500 g;
- Resolution (rms): 0.005g;
- Weight: 0.02 N.

The frequency response of the whole measuring chain is flat, in the frequency range from 3 to 3000 Hz, with an accuracy of ± 5%.

Serial numbers of the employed accelerometers are listed in the above reported table. The instrumentation is submitted to a calibration program in accordance with internal procedures.

### 3.3. Data acquisition and processing instrumentation

During all the tests the shaker was controlled by a computer (the digital system LMS International) which is composed by an acquisition panel of 16 channels and by a PC. This control system generates the motion with the requested characteristics and feeds-back the shaker motion using the signal coming from the accelerometer chosen for the control.

Analogue signals coming from the accelerometers were amplified and conveyed to an analogue/digital converter, which sent the data to the disk storage of the aforementioned minicomputer for subsequent processing.

The block scheme of the excitation, acquisition and processing equipment is shown at page 13.

### 4. TEST RESULTS

Figures at pages 15 - 17 show the absolute response function relevant to the control accelerometer and the frequency transfer functions relevant to the measuring positions placed on the item obtained during the frequency response investigation test in Z direction (during this test measuring position C wasn’t instrumented).

Figures at pages 18 - 21 show the absolute response function relevant to the control accelerometer and the frequency transfer functions relevant to the measuring positions placed on the item obtained during the frequency response investigation test in X direction (during this test measurement position MPC wasn’t installed).

Figures at pages 22 - 25 show the absolute response function relevant to the control accelerometer and the frequency transfer functions relevant to the measuring positions placed on the item obtained during the frequency response investigation test in Y direction.
4.1. General remarks

At the end of the tests, at a visual inspection, no damages were detected on the tested equipments.

In all the measurement positions, we have transfer function module value under the threshold value fixed ad 5; due to this, for an excitation level of 0.1 g at the base of the rack, the vibration level inside the rack is under the threshold of 0.5 g indicated in the “Test objective” paragraph. The test result is POSITIVE.

The results of further checks on the unit are of CUSTOMER’s responsibility.
LIST OF FIGURES

Page 13: Block diagram of the excitation and measuring equipment.
Page 14: List of the tests
Page 15-37: Tests recordings results of the vibration tests

PHOTO DOCUMENTATION

Photo 1: Control position for vertical shaking table
Photo 2: Control position for horizontal shaking table
Photo 3: Measurement positions A and B
Photo 4: Measurement positions A and C
Photo 5: Rack on vertical shaking table
Photo 6: Rack on horizontal shaking table
Photo 1: Control position for vertical shaking table

Photo 2: Control position for horizontal shaking table
Photo 3: Measurement positions A and B

Photo 4: Measurement positions A and C
Photo5: Rack on vertical shaking table

Photo6: Rack on horizontal shaking table
BLOCK DIAGRAM RELEVANT TO THE DYNAMIC TESTS

- Shaker
- Unit under test
- Fixture
- Measuring accelerometers
- Control accelerometer
- Measuring amplifiers
- Power amplifier
- D/A converter
- A/D converter
- Computer for motion control and data acquisition
- Peripheral units
- Oscilloscope
## TEST LIST

<table>
<thead>
<tr>
<th>N.</th>
<th>Test</th>
<th>Excitation axis</th>
<th>Test parameters</th>
<th>Duration</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insulated rack</td>
<td>Z</td>
<td>Frequency range: 10-500 Hz Acceleration: 0,1 g (g=9,81 m/s²) Sweep rate: 1 oct/min</td>
<td>1 sweep</td>
<td>15 - 17</td>
</tr>
<tr>
<td>2</td>
<td>Insulated rack</td>
<td>X</td>
<td>Frequency range: 10-500 Hz Acceleration: 0,1 g (g=9,81 m/s²) Sweep rate: 1 oct/min</td>
<td>1 sweep</td>
<td>18 - 21</td>
</tr>
<tr>
<td>3</td>
<td>Insulated rack</td>
<td>Y</td>
<td>Frequency range: 10-500 Hz Acceleration: 0,1 g (g=9,81 m/s²) Sweep rate: 1 oct/min</td>
<td>1 sweep</td>
<td>22 - 25</td>
</tr>
</tbody>
</table>
Sine Control

Project: AB01309
Section: Section 1
Run: Sine_3
Date: Thu Feb 26 2009 16:17:54

Sweep done: 1
Sweep direction: Up
Sweep mode: Log
Sweep rate: 1 Oct/min
Control strategy: Average
Reference id:
Point id: CP1
Frequency resolution: Variable
Mechanical Test Laboratory – Sine Control

Project: AB01309
Section: Section 1
Run: Sine_3
Date: Thu Feb 26 2009 16:17:54

Sweep done: 1
Sweep direction: Up
Sweep mode: Log
Sweep rate: 1 Oct/min
Control strategy: Average
Reference id: CP1
Point id: MPB
Frequency resolution: Variable

FRF (Harmonic) MPB:+X/CP1:+X

14.51 39.47
1.00e-3 10.00 Hz
-180.00 180.00 Phase

Log
### Project: AB01309

<table>
<thead>
<tr>
<th>Section: Section1</th>
<th>Sweep done: 1</th>
<th>Control strategy: Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run: Sine_3</td>
<td>Sweep direction: Up</td>
<td>Reference id: CP1</td>
</tr>
<tr>
<td>Date: Thu Feb 26 2009 16:17:54</td>
<td>Sweep mode: Log</td>
<td>Point id: MPC</td>
</tr>
<tr>
<td></td>
<td>Sweep rate: 1 Oct/min</td>
<td>Frequency resolution: Variable</td>
</tr>
</tbody>
</table>

### Graph:

- **Control strategy:** Average
- **Point id:** MPC
- **Reference id:** CP1
- **Frequency resolution:** Variable

**Log/Phase Graph**

- **FRF (Harmonic)**: MPC:+X/CP1:+X

**Graph Details**

- **Sweep done:** 1
- **Sweep direction:** Up
- **Sweep mode:** Log
- **Sweep rate:** 1 Oct/min

**Graph Axes**

- **X-axis:** Hz
- **Y-axis:** Gain (10.00), Phase (-180.00 to 180.00)

**Graph Points**

- **Gain Values:**
  - 1.00e-3
  - 14.43

- **Phase Values:**
  - 14.43
<table>
<thead>
<tr>
<th>Project: AB01309</th>
<th>Sweep done: 1</th>
<th>Control strategy: Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section: Section1</td>
<td>Sweep direction: Up</td>
<td>Reference id: CP1</td>
</tr>
<tr>
<td>Run: Sine_4</td>
<td>Sweep mode: Log</td>
<td>Point id: MPA</td>
</tr>
<tr>
<td>Date: Thu Feb 26 2009 16:17:54</td>
<td>Sweep rate: 1 Oct/min</td>
<td>Frequency resolution: Variable</td>
</tr>
</tbody>
</table>

**FRF (Harmonic) MPA:+Y/CP1:+Y**

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Magnitude</th>
<th>Phase (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.25</td>
<td>12.43</td>
<td>33.61</td>
</tr>
<tr>
<td>10.00</td>
<td>500.00</td>
<td></td>
</tr>
<tr>
<td>-180.00</td>
<td>180.00</td>
<td></td>
</tr>
<tr>
<td>1.00e-3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Graphical Representation:**

- Magnitude
- Phase
- Frequency

**Chart Details:**

- Control strategy: Average
- Point id: MPA
- Reference id: CP1
- Sweep rate: 1 Oct/min
- Frequency resolution: Variable
- Sweep mode: Log
- Sweep direction: Up
- Sweep done: 1
### Mechanical Test Laboratory – Sine Control

**Project:** AB01309  |  **Sweep done:** 1  |  **Control strategy:** Average

**Section:** Section 1  |  **Sweep direction:** Up  |  **Reference id:** CP1

**Run:** Sine_4  |  **Sweep mode:** Log  |  **Point id:** MPB

**Date:** Thu Feb 26 2009 16:17:54  |  **Sweep rate:** 1 Oct/min  |  **Frequency resolution:** Variable

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#### FRF (Harmonic) MPB:+Y/CP1:+Y

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Magnitude</th>
<th>Phase (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00</td>
<td>1.69</td>
<td>11.53</td>
</tr>
<tr>
<td>500.00</td>
<td>180.00</td>
<td>23.74</td>
</tr>
</tbody>
</table>