Dynamic Base Isolation of Panels Under Different Dynamic Excitations

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INTRODUCTION

The design of Nuclear Power Plants implies the structural integrity and operability verifications of structures, components and equipment against dynamic exitations caused by carthquakes, operational and accident transient conditions, external events such as pressure waves and missile impacts.
For electrical equipment such as panels, the dynamic qualification of the internal instrumentation requires that the medium high frequency components of some design excitations do not cause significant local amplifications . The dynamic base isolation makes this requirement easier to be met. It consists of a combination of spring and damper elements put at the base of the panel (and eventually at the top for high rise configurations), providing a panel dynamic decoupling with respect to the medium high frequency components of the excitation and a displacement limitation against the low frequency components.

CRITERIA FOR ISOLATORS SELECTION

Type Selection

The isolator type selection is one specific phase of the qualification procedure for class 1E electrical equipment typically shown in Table 1.
Among various configurations of dynamic isolators available on the market, the specific choice is based on two main parameters:

- the isolator typical frequency, governing the global dynamic characteristics of the combined panel plus isolators system,
- the isolator intrinsic damping, mainly characterizing the global damping properties of the combined system.

The selection of such parameters relies on the theoretical foundamentals of the dynamic isolation (against sinusoidal excitation typically), indicating that:

- a good isolation efficiency requires that the ratio between the dominating frequency of the exicitation and the foundamental frequency of the isolated system be sufficiently high (typically larger than 3).
- taking into account the opposite role of the system damping in the two regions a) of deamplification (required against medium/high frequency excitations) and b) of amplification (possible as a consequence of low frequency excitations) an isolator type exibiting increasing damping values at higher strains is recommended.

Isolators with damping characteristics varying between 4% of critical at small strains and more than 10%, for typical earthquake induced strains are, available on the market.

Isolators Characteristics

For a given type, isolators of a specific size are characterized both statically, by mean of axial and radial static deflection curves, and dynamically, by axial and radial response amplification curves, against sinusoidal or randon excitations of suitable amplitude (typically $\pm$ 1 mm) in the interesting frequency range (for instance 1 : 70 Hz).
As an example such characteristics are shown in fig. 1 for a steel type isolator, made with a spring contained in a steel wire ball providing damping properties.

Layout considerations

The number, location and mounting directions of the chosen isolators can be defined for given geometrical and inertia properties of the panel and layout boundary conditions.
For high rise panels additional stabilizers may be required also.
For any principal direction a specific check of the resulting isolator stiffness is needed, to avoid excessive displacements and run-stop impacts but to allow strain levels compatible with the required damping magnitude. The resulting stiffness can be obtained from the deflection curves, taking into account the mounting direction and possible preloads for each element. A good distribution of the resulting stiffness must be finally verified to avoid concentrations on single elements.

ANALYSIS VALIDATION WITH TEST RESULTS

In order to validate an analysis procedure, to be extensively used for the dynamic qualification of isolated panels, a prototypical panel has been vibration tested with the PERSEUS shaking table at the Ansaldo Boschetto Facilities in Genoa.
After an independent experimental check of the static and dynamic characteristics provided by the isolator supplier, transmissibility characteristics and forced responses under several dynamic excitations with different frequency contents were evaluated for the isolated panel and for the panel rigidly connected to the shaking table.
Tipical instructure responses spectra measured at the top and bottom of the panel are shown in fig. 1 and compared with the base excitation in case of assumed aircraft impact conditions. Following results are worth note:

- peak responses occur at the foundamental frequency of the isolated panel (about 6 Hz).
- A small variation with the panel height of the peak responses indicates that the dominating mode is a quasi rigid panel translation on the isolators.
- The dynamic decoupling obtained with the isolators significantly filters the high frequency components of the excitations.

The measured responses have been also satisfactorily compared with the results of a dynamic analysis of a FEM model of the isolated panel. Fig. 1 typically presents such a comparison for the X impact case.

The analysis procedure consists of a linearization of the isolators stiffness characteristics, a response spectrum analysis of the combined model with strain weighted average modal dampings (Ref./1/) and a direct development of the instructure response spectra for the device qualification (Ref.2).

APPLICATIONS

To show the advantages of the base isolation predictable with the validated analytical procedure, two typical different applications are presented:

- an Instrumentation Rack with a width dimension of 72" subject to seismic and medium/high frequency hydrodynamic excitations is analysed on a fixed base and with base isolation (see fig. 2).
- An Inverter Panel formed with 4 coupled units, resting on a common isolated base slab is analyzed against seismic and high frequency missile impact excitations (see fig. 3).

The dynamic decoupling and the redistribution of the modal participation factors towards the foundamental low frequency modes, obtained with the base isolators, significantly reduce the hydrodynamic and impact responses (by a factor of 4 for both horizontal and vertical hydrodynamic peak responses), whereas the addtional damping effects of the isolators and the use of top stabilizers limit the maximum seismic responses to still acceptable levels.

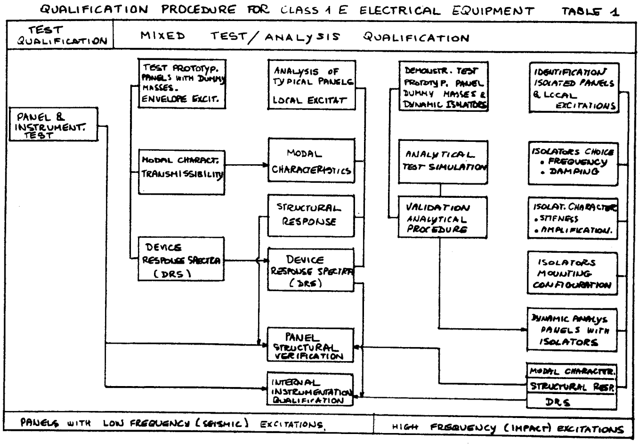
CONCLUSION

The base dynamic isolation of electrical panels is a practical tool to make easier the qualification of internal instruments under dynamic base excitations of different frequency characheristics.

REFERENCES

1.-VITI et al "SAP 87" Ansaldo document n° NT-AST-87031
2.-VITI et al "CYRANO 2" Ansaldo document n° STUOAST 0010.

QUALIFICATION PROCEDURE FOR CLASS 1 E ELECTRICAL EQUIPMENT TABLE 1



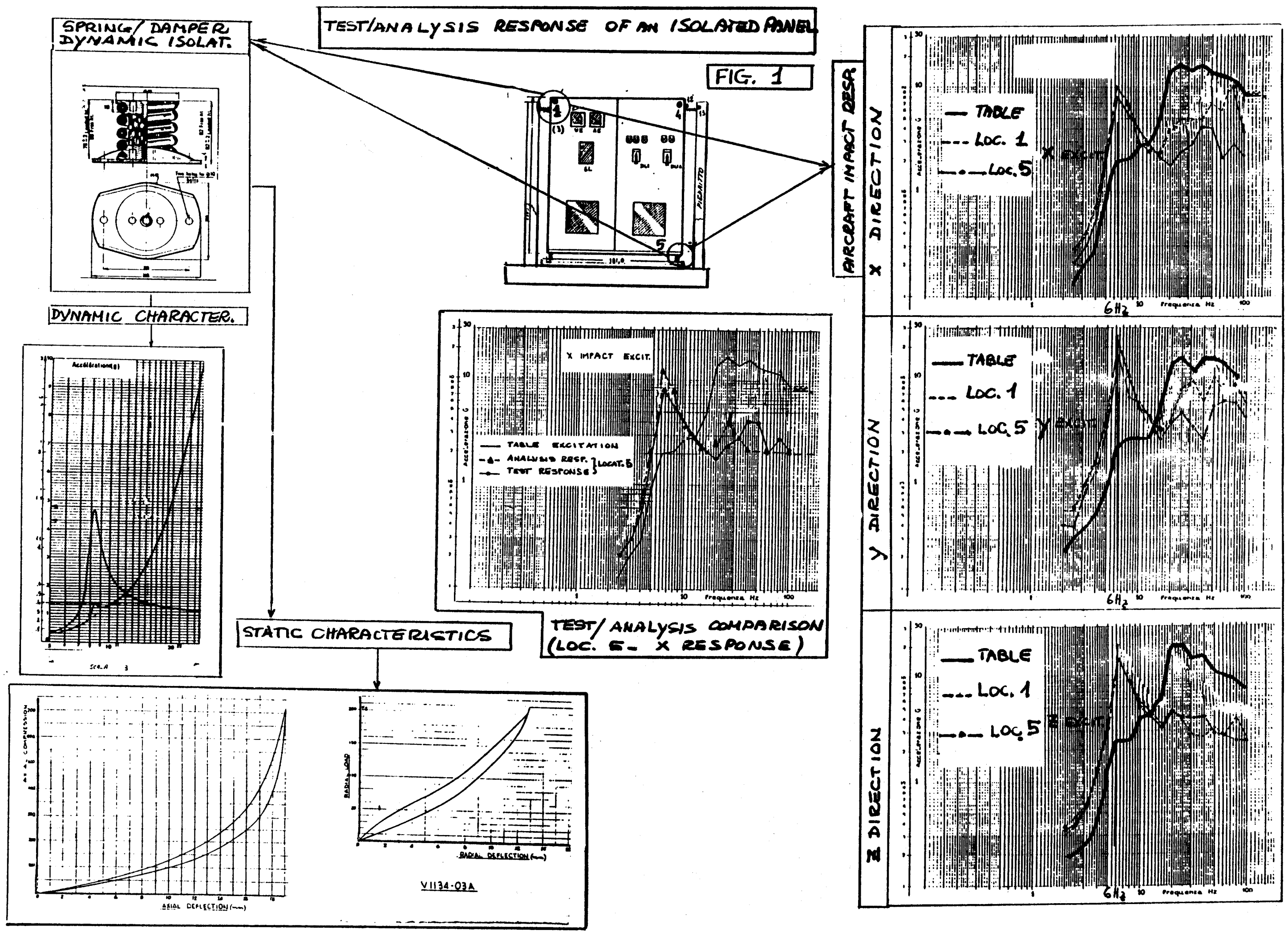
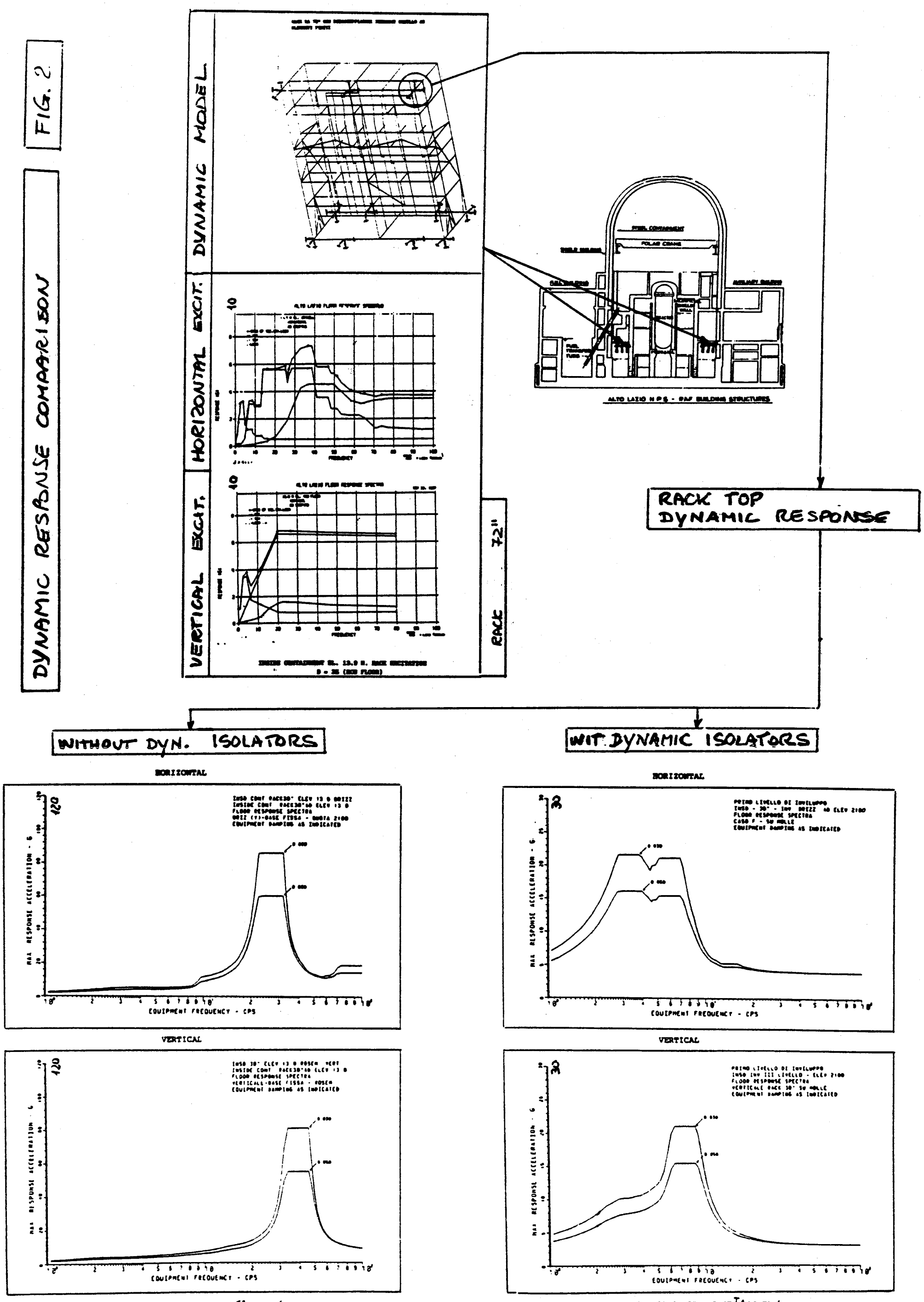
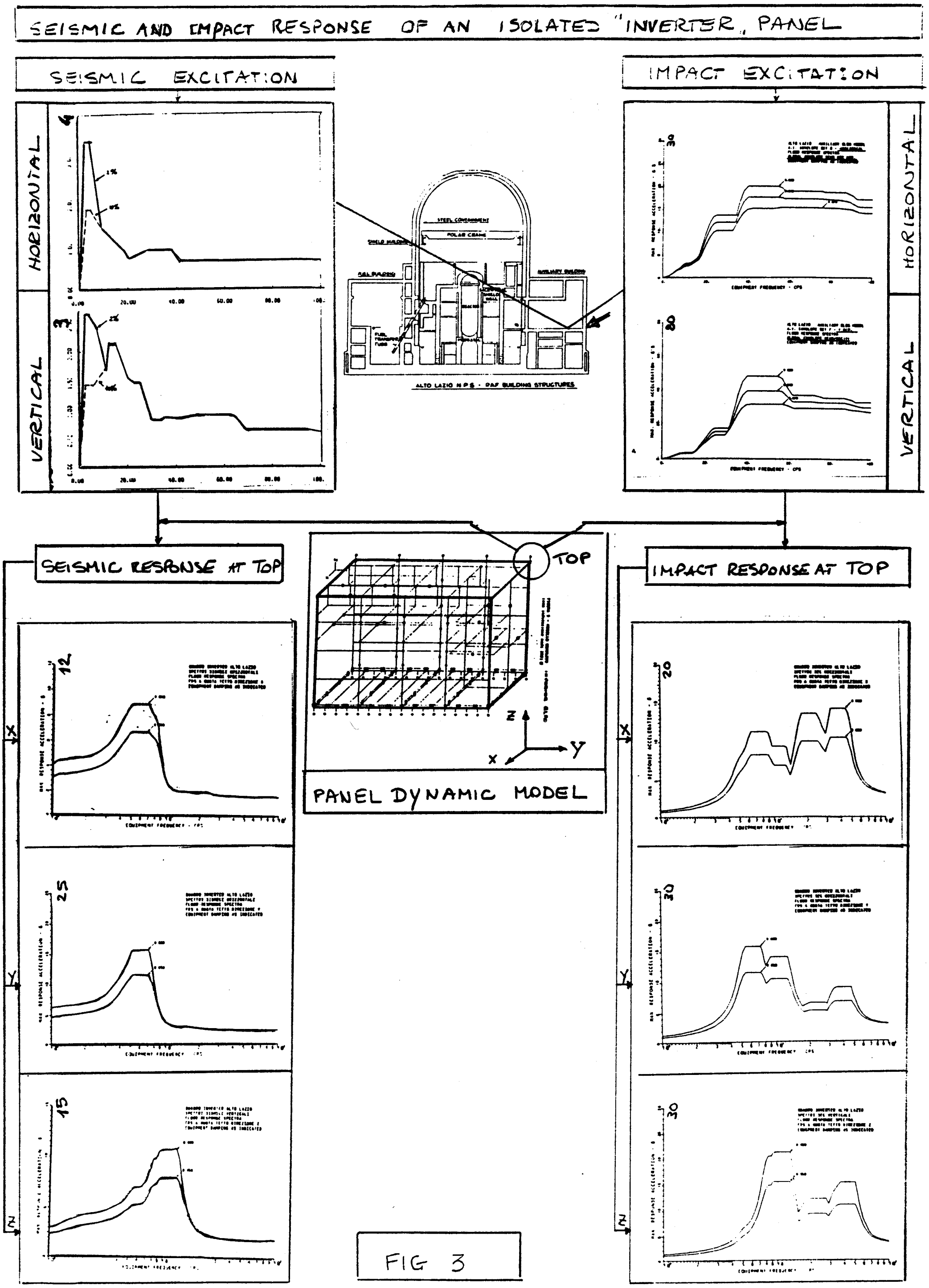

TEST/ANALYSIS RESPONSE OF AN ISOLATED PANEL
SPRING/ DAMPER DYNAMIC ISOLAT.
DYNAMIC CHARACTER.
STATIC CHARACTERISTICS
AIRCRAFT IMPACT DESR
X DIRECTION
Y DIRECTION
Z DIRECTION
TABLE
Loc. 1
Loc. 5
X EXCIT.
Y EXCIT.
Z EXCIT.
6Hz
Frequenza Hz
X IMPACT EXCIT.
TABLE EXCITATION
ANALYSIS RESP.
TEST RESPONSE
LOCAT. 5
TEST/ ANALYSIS COMPARISON (LOC. 5 - X RESPONSE)
AXIAL DEFLECTION (mm)
RADIAL DEFLECTION (mm)
RADIAL LOAD
V1134-03A

FIG. 1

DYNAMIC RESPONSE COMPARISON

FIG. 2





SEISMIC AND IMPACT RESPONSE OF AN ISOLATED "INVERTER" PANEL
SEISMIC EXCITATION
IMPACT EXCITATION
HORIZONTAL
VERTICAL
SEISMIC RESPONSE AT TOP
IMPACT RESPONSE AT TOP
TOP
PANEL DYNAMIC MODEL
ALTO LAZIO N.P.S. - PAF BUILDING STRUCTURES
STEEL CONTAINMENT
POLAR CRANE
X
Y
Z

FIG 3