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Seismic qualification of electrical cabinet

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Electrical cabinets are widely used in power control systems. Electrical cabinet is housing for many delicate protection, measuring and control equipments like relays, meters, circuit breakers, logic device, printed circuit board etc. Seismic load should be one of criteria for selection of electrical enclosures. Seismically qualified Electrical cabinet ensures proper functioning and safety of equipment installed in it during and after seismic event. Electrical enclosures should not amplify seismic waves and should withstand seismic load without undergoing any physical failure. A typical Seismic qualification test carried out on an electrical enclosure is discussed in this paper.

Keywords: *resonance frequency, seismic qualification, electrical cabinet.*

1.0 INTRODUCTION

An earthquake is the sudden, rapid shaking of the earth, caused by the breaking and shifting of subterranean rock as it releases strain that has accumulated over a long time. Earthquake causes massive damage to structures and equipment in addition to loss of life. Identifying potential hazards ahead of time and advance planning can reduce failure of structures and equipment or loss of life due to earthquake. Failure of structures and equipment can be prevented by considering seismic load during design. Functioning of electrical equipment during and after earthquake ensures uninterrupted power supply which is highly essential for timely rescue operation and functioning of critical facility such as hospital, nuclear power plant etc.

The seismic qualification of equipment should demonstrate its ability to perform its safety function during and after the time it is subjected to the forces resulting from earthquakes. The most commonly used methods for seismic qualification are predict the equipment's performance by analysis and test the equipment under simulated seismic conditions. Earthquake Engineering and Vibration Research Centre (EVRC) of Central Power Research Institute at Bangalore is equipped with the state-of-the-art facilities for testing of structures, components and electrical equipment using a Tri-axial shaker system.

2.0 TRI-AXIAL SHAKER SYSTEM AT CPRI

Earthquake engineering laboratory of Central Power Research Institute is equipped with the tri-axial shaker system with six degrees of freedom, capable of performing a diverse range of seismic qualification test requirements on equipment, sub-assemblies and components as per National / International standards. The shake table is of size 3 m x 3 m used to simulate earthquake vibration simultaneously in two horizontal and one vertical axes. Maximum pay load is 10,000 Kg and frequency range of vibration is 0.1 to 50 Hz.

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The advanced control system allows the reproduction of earthquake ground motions with high fidelity and little distortion. The seismic qualification tests on various electrical equipments like control panel, switchgear cubical, instrument transformer, electrical cabinet, outdoor breaker, transformer bushing etc. are being conducted using the tri-axial shaker system as per National and International standards.

3.0 SEISMIC QUALIFICATION OF ELECTRICAL CABINET

Electrical cabinets are widely used in power control systems. Electrical cabinet is housing for protection, measuring and control equipments. Electrical cabinet should be capable of withstanding seismic load without any physical failure. In electrical cabinet, protection and control equipments are mounted at different locations inside the cabinet and also on doors. Amplified base acceleration may cause failure of the cabinet or the equipment mounted in it.

Standard practice for seismic qualification of an electrical cabinet involves determination of its dynamic characteristics like resonance frequencies and damping by response search test using base excitation method, subjecting the electrical cabinet to tri-axial seismic vibration in two horizontal and one vertical axes simultaneously and then repeating resonance search test after seismic test. Seismic qualification test carried out on a typical electrical cabinet at EVRC is presented in this technical paper.

3.1 Mounting

At most care is taken to ensure that mounting of the cabinet on the shake table during seismic qualification is exactly same as in service condition. Electrical cabinet is usually grouted to floor. Similar arrangement is made while mounting the cabinet on the shake table for seismic testing. Photograph of electrical cabinet mounted on shake table is shown in Figure 1.

Dummy weights (in the form of sand bag / MS plates) are placed at various locations to simulate equipment mass. All the fasteners like bolts, nuts and screws are tightened with specified torque to check loosening,if any after test.

Accelerometers were mounted on electrical cabinet at top, base and other critical locations to determine natural frequencies, damping coefficients and amplification of input vibration. Strain gauges were mounted at critical locations on the panel to check magnitude of stresses induced due to seismic vibration and are compared with allowable material stress.

FIG. 1 ELECTRICAL CABINET MOUNTED ON TRI-AXIAL SHAKE TABLE

3.2 Recommended Test Procedure

The steps involved in the seismic qualification of electrical cabinet are listed below:

a. Tightening all fasteners with specified torque

b. Resonance search test (Before seismic test)

c. Seismic qualification test

d. Resonance search test (After seismic test)

e. Checking all fasteners for tightness

3.3 Resonance Search Test (Before Seismic Test)

The electrical cabinet is mounted on the shake table. Accelerometers and strain gauges are mounted on the cabinet. Resonance search test is carried out by base excitation method to determine dynamic characteristics of cabinet before seismic test. Tri-axial shaker system is excited with sinusoidal sweep from 1 to 50 Hz with a constant acceleration of 2 m/s^2 along all the three axes. Frequency sweep rate is 1 Oct/minute [1]. During sinusoidal sweep, table acceleration and response acceleration of the electrical cabinet are recorded and resonance frequencies in the frequency range of 1 Hz to 50 Hz along all the three axes are identified. The Resonance frequencies identified are shown in Table 1.

TABLE 1

RESONANT FREQUENCIES RECORDED BEFORE SEISMIC TEST

Sl. No.	Axis	Resonance Frequencies, Hz
1	longitudinal	5.0
2	transverse	6.5
3	vertical	41.0

3.4 Seismic Qualification Test

The Electrical cabinet with critical equipments and components replaced by equivalent mass was subjected to Seismic test. The acceleration levels of Required Response Spectrum at 5% damping prescribed in IS 1893, Part 1, Zone V, soft soil condition is used to generate response spectrum compatible time histories and these time histories are used to excite the Shake table [2]. Required Response Spectrum (RRS) and Test Response Spectrum (TRS) are shown in Figure 2.

During seismic test, acceleration and strain values on electrical cabinet were recorded. Maximum acceleration recorded is at top of electrical cabinet along transverse axis and it is as shown in Figure 3.

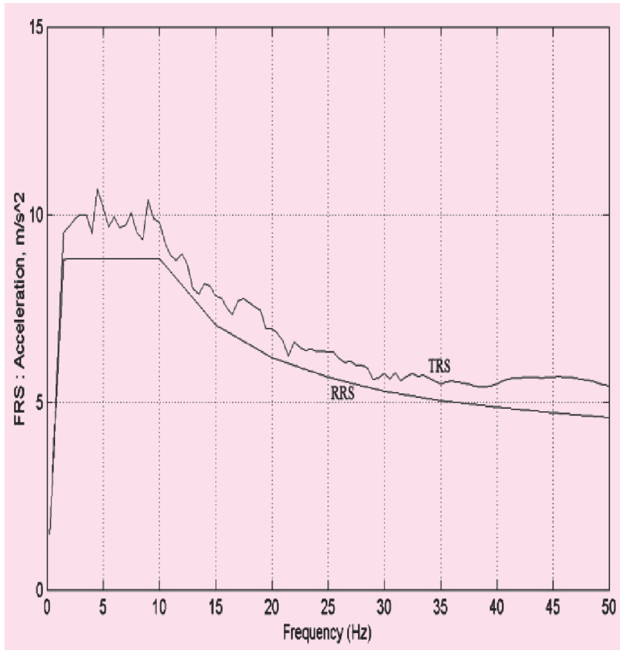

FIG. 2 RRS AND TRS DURING SEISMIC TEST

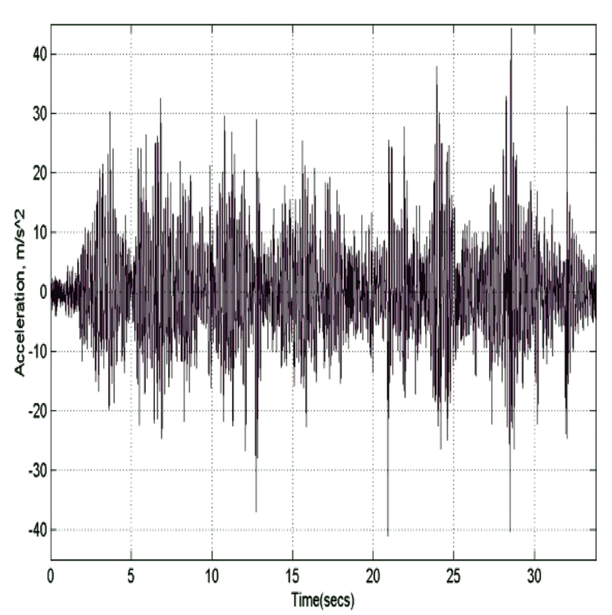

FIG. 3 TIME HISTORY OF ACCELERATION RECORDED DURING SEISMIC TEST, PEAK VALUE = +44.311 AND -41.022 M/S^2

3.5 Resonance Search Test (After Seismic Test)

After carrying out seismic test on the specimen, Resonance search tests are carried on the cabinet to identify the resonance frequencies. Resonance frequencies identified are shown in Table 2.

TABLE 2		
RESONANT FREQUENCIES RECORDED AFTER SEISMIC TEST		
Sl. No.	**Axis**	**Resonance Frequencies, Hz**
1	longitudinal	5.0
2	transverse	6.5
3	vertical	41.0

3.6 Acceptance Criteria

After carrying out all the above tests, cabinet is subjected to visual inspection for permanent deformation and visual damage. The Structural integrity is checked by comparing the pre and post seismic resonance search test results. From the resonance search test results it is clear that there is no change in its resonance frequencies identified before and after seismic test. Hence it can be concluded that the electrical cabinet's structural integrity is confirmed. Also all fasteners are checked for tightness after seismic test with calibrated torque wrench. The cabinet is seismically qualified for Indian Seismic Zone V (as per IS:1893 – Part 1)

4.0 CONCLUSIONS

Analysis is one of the methods recommended by Standards for Seismic qualification of electrical cabinet. However it is very complex to simulate the mass of equipment, connections & joints adopted in the fabrication of cabinet in the mathematical modelling and finite element analysis. By analysis it is not possible to check the loosening of fasteners.

Unless preliminary tests are conducted the damping values of the cabinet cannot be evaluated. Damping value is one of the important design parameter required for analysis. It is preferable to qualify the cabinet for earthquake loading prior to mounting sensitive equipment like protection relays, measuring instruments etc., to prevent premature failure during seismic testing of panels with all the equipment mounted since the testing is expensive.

CPRI has the–state-of-the–art facilities to carry out seismic tests on Electrical equipment and control panels as per National and International standards. Manufacturers can utilise the available facilities and expertise of EVRC in developing seismic qualified equipment.

5.0 ACKNOWLEDGEMENT

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REFERENCES

[1] IEEE Standard 693, Recommended Practice for Seismic Design of Substations.

[2] IS 1893, Part 1, Criteria for earthquake resistant design of structures, General provisions and buildings, 2009.