Seismic Qualification Of Electrical Power Equipments

Dr.R.Ramesh Babu, R.Panneer Selvam, Prabhakar Hegde, V.Srinivasamurthy and K.B.Manjunath

Abstract—**Failures of power Equipment due to earthquakes are common. Seismic qualification of critical power equipments is essential to ensure safe and reliable power supply. To cater the needs of industries and power utilities, facilities are available at CPRI for conducting seismic qualification tests on power equipment. Seismic qualification tests were carried out on many electrical equipments using tri-axial shaker system to evaluate their adequacy in resisting earthquake loads and to study their performance and reliability during earthquake.**

I. Introduction

Reliability of any system mainly depends upon the dynamic behavior of equipment, components and hardware in the system when subjected to vibration. Major cause of vibration that damages the power plant equipment such as generators, switch-gears, transformers, etc., is the seismic excitation or support motion. To ensure the safety of equipment against such forces, it is necessary to design and test these equipment for the seismic forces. This paper deals with the state-of - the- -art facilities available at Central Power research Institute, Bangalore for carrying out dynamic qualification tests on equipment for their acceptance before installation. Equipment being qualified must demonstrate that it can perform its safety function during and after an earthquake. The high performance shake table at CPRI has been utilized for testing many electrical equipments like transformers, Electrical control panels, battery Back ups, UPS etc., for seismic qualification.

II. Seismic Design

Recent seismic events around the world have provided new insight into the way structures and power equipments perform when subjected to earthquake related ground motion. These events have focused the attention of government agencies, the scientific community and the general public on safety hazards and potential losses associated with structures and power equipments that perform poorly during earthquakes. As a result, there is growing national emphasis on seismic risk assessment, seismic design requirements for new power plant structures and equipments, and seismic retrofit of existing structures.

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Scientists have begun to estimate the locations and likelihoods of future damaging earthquakes. Sites of greatest hazard are being identified, and definite progress is being made in designing power equipments and structures that will withstand the effects of earthquakes.

III. Seismic Testing

Due to increased population and progress in advanced technological activities, the risk of earthquake is much higher than before. Hence the safety against earthquakes is strongly required for equipments in Power plants in general and nuclear power plants in particular [1] and other power transmission line networks. To improve our understanding of the response of these structures and the equipments under earthquakes, three approaches could be adopted, i.e., site investigation of earthquake damage, theoretical analysis and structural test. Though the computer and numerical techniques are advanced, the structural testing methods are still the most powerful, basic and determined methods in studying structural seismic behavior.

IV. Seismic Simulation

The goal of seismic simulation is to reproduce the postulated earthquake environment in a realistic manner. The form of the simulated seismic motion used for the qualification of equipment by analysis or testing can be described by one of the following functions:

(1) Response Spectrum
(2) Time History
(3) PSD

The response spectrum produces information on the maximum response of single-degree-of-freedom oscillators as a function of oscillator frequency and damping when subjected to an input motion. The frequency content and the peak value zero period acceleration (ZPA) of the input motion is indicated. Currently there are several methods available for seismic simulation testing of structural systems. The possible seismic test methods for structures are

1) Quasi -static cyclic test,
2) Pseudo-dynamic test,
3) shaking-table test.

Among the above, quasi-static cyclic tests are carried out on components or sub systems of buildings and shake table studies and pseudo-dynamic tests for large systems and scaled models.

Shaking table test is more realistic method of earthquake testing than pseudo dynamic method. The shaking table test is economic, tangible, and reliable validation test to assess the seismic safety and reliability of buildings. Shaking tables are usually square or rectangular stiff planar platforms moved by servo-hydraulic actuators to simulate earthquakes. Shaking table can be effectively used for checking structural adequacy of the earthquake-resistant design and to validate the mathematical model of electrical equipment and housing structures. In fact, most of the electrical equipment can be tested by shaking table testing method so long as the system has enough capacity to carry the test specimen.
Operating Basis Earthquake (OBE) [2] is defined as an earthquake that could reasonably be expected to occur at the plant site during the operating life of the plant considering the regional and local geology and seismology and specific characteristics of local subsurface material. Safe shutdown earthquake (SSE) is defined as an earthquake that that produces the maximum vibratory ground motion considering the earthquake potential at the site location for which certain structures, systems, and components are designed to remain functional.

The main purposes of carrying out seismic simulation tests are to study the seismic responses of accelerations, displacements and strains at critical locations of structures, to identify the locations of structural crack and the weakness points and to determine the collapse pattern and failure mechanism. Prior to seismic simulation tests, preliminary dynamic tests are conducted on the system to evaluate their dynamic characteristics viz., the natural frequencies, damping ratio and vibration modes etc.,

V. PRELIMINARY DYNAMIC TESTS

Though exploratory vibration tests are generally not part of the seismic qualification requirements, but are carried out on equipment to determine the best test method for qualification or to determine the dynamic characteristics of the equipment. These low input level vibration tests are normally described as resonance searches. They are generally performed at input levels well below the required seismic qualification vibration level. These tests can be performed in several ways. The most common method is the resonance search that is performed as a slowly swept sinusoidal vibration test with the input uni-axial. The equipment responses are measured to determine resonances and cross coupling. A second method involves impacting the equipmentusing impact hammer in a controlled manner at critical points on the structure, capturing the impact (force input) and response data and computing the transfer function between impact and response locations.

VI. SHAKE TABLE TESTS

Specimens of interest are mounted on the shake table in a manner that simulates the intended service mounting and tests are carried out simulating design or postulated earthquakes. The mounting method is same as that recommended for actual service using the recommended bolt size, type, torque, configuration and weld pattern and type, etc.

The dynamic behavior of the structure and its damage pattern under earthquake with great magnitude are reproduced using the required response spectra furnished by the end user of the test specimen. Functional and vibrational response parameters are continuously monitored during seismic testing. Accelerometers and strain gauges are mounted at critical locations and their responses are monitored during testing using data acquisition system. In addition sufficient monitoring instrumentation are used to evaluate the functionality of the equipment before, during and following its vibration test exposure.

The seismic qualification tests are done on test specimen / equipment to verify the equipment's ability to perform its safety function during and after the time it is subjected to the forces resulting from one Safe Shut down Earthquake. In addition, the equipment must withstand the effects of five number of Operational Basis Earthquake prior to the application of an SSE.

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Fig. 1. A typical electrical panel under shake table test in CPRI.

The qualification criteria is that the Test Response Spectra (TRS) generated during testing by the skaker system should envelope the Required Response Spectra(RRS). Fig. 2 shows the TRS and RRS of a typical shake table test.

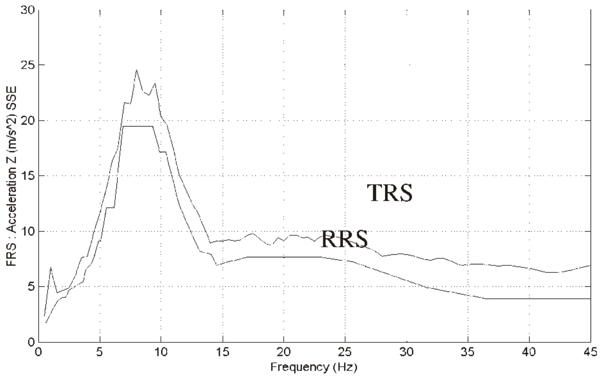

Fig. 2. TRS and RRS of a typical shake table test.

As a result of this test, the structure is proved to ensure safety, or too weak to resist a destructive earthquake. The weak points of structure are determined, and suggestions and modifications can be put forward, before the construction of prototype structures. Extensive shake table tests are conducted at many research and academic institutes to study earthquake resistant design of civil engineering structures, and to qualify critical equipment like computer control systems, switching relay banks, electrical control panels and nuclear plant cooling pumps and turbines.

These tests confirm the reliability of the equipment during and after earthquake without undue risk to the health and safety of the public, are adequately designed to remain functional.

VII. TRI - AXIAL SHAKER SYSTEM AT CPRI BANGALORE

Earthquake engineering laboratory housing 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 has been established at Central Power Research Institute CPRI, Bangalore in the year 2003. The tri-axial shaker system consisting of a shaking-table is a unique facility that can strictly simulate the earthquake ground motion without any distortion.

The shaking table can vibrate in one axis to three axes with six degrees of freedom. The advanced control system allows the reproduction of earthquake ground motions with high fidelity and little distortion.. Table 1 shows salient features of high-performance shaker system at CPRI, Bangalore. The seismic qualification tests are being conducted using the tri-axial earthquake simulation system, which features a 10-ton pay load capacity shake table of all-welded steel construction. An advanced control system allows the reproduction of earthquake ground motions with high fidelity .

Table 1 Salient features of shaking table facilities of CPRI, Bangalore

Maximum Payload	10 Tons		
Table dimension	3 x 3 m		
Exciting direction	X, Y, Z (Simultaneous / Sequential)		
Degrees of freedom	Six (3 Translatory and 3 Rotational)		
Max. Height of the specimen	10 m		
Driving Type	Servo-Hydraulic Control		
Direction	X	Y	Z
Acceleration, m/s^2	±10	±10	±10
Velocity, m/s	±1	±1	±1
Displacement, mm	±150	±150	±100
Frequency	0.1 to 50 Hz		
Allowable Moment	Overturning		Yawing
	40 ton.m		10 ton.m
Actuators Vertical Horizontal	 4 nos. of 180 KN 4 nos. of 150 KN		

VIII. CONCLUSIONS

For seismic qualification of electrical equipments , their analytical design could be validated by carrying out tests during design development phase or on prototype. CPRI has experience with the testing techniques both from the dynamic and static view point. CPRI, is well equipped with the-State-of- the-Art tri-axial shaker system can satisfy the demands in seismic qualification, CPRI offers the customers access to R&D in seismic qualification and multi-disciplinary expertise. Power utilities and manufacturers in our country can utilize this centre in ensuring reliable power supply for which this centre is ebtablished under IX five year plan (Ministry of power).

ACKNOWLEDGMENT

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REFERENCES

[1] ANSI/IEEE Std.323-1983 IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power generating stations.

[2] IEEE Std.344-1987 IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power generating stations.