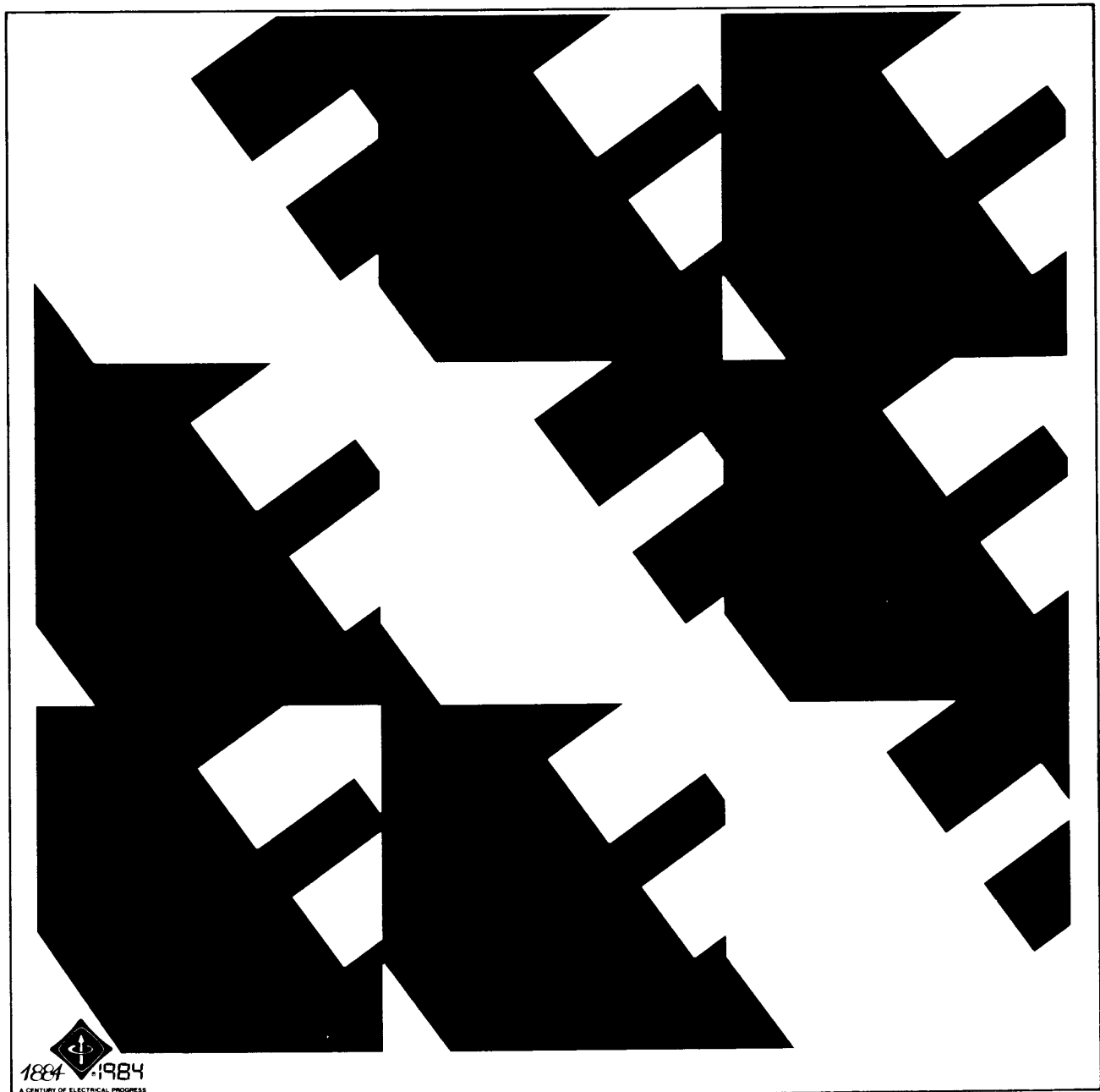


IEEE Recommended Practices for Seismic Design of Substations



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1. Introduction

1.1 Scope. These recommended practices contain recommendations for the seismic design of substation facilities.

1.2 Background. The evolution of seismic design practices is related to the occurrence of major earthquakes. The 1906 San Francisco, the 1923 Kanto, Japan, the 1925 Santa Barbara, and the 1933 Long Beach earthquakes all led to design and building code changes. These changes were all improvements but were basically static load design methods. These methods did not take into account the dynamic behavior of the equipment or structure. However, starting about 1950, building codes such as the Uniform Building Code [4]¹ began to incorporate dynamic behavior concepts into the static equivalent load method.

The type and amount of damage sustained by power equipment and structures during the San Fernando, California earthquake of February 9, 1971, pointed out the necessity for the Power Industry to consider the dynamic behavior of equipment and structures and to reassess anticipated ground motions for use in analysis and design.

2. References

[1] AISC Specifications for Design, Fabrication, and Erection of Structural Steel for Building, 1978.²

[2] ANSI/IEEE Std 344-1975, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

¹ Number in brackets correspond to those of the References listed in Section 2.

² AISC publications are available from the American Institute of Steel Construction, 400 North Michigan Avenue, Chicago, Illinois 60611.

[3] ASME Boiler and Pressure Vessel Code, 1977.³

[4] ICBO Building Code, 1982.⁴

[5] NEWMARK, N. M. and ROSENBLUETH, E. *Fundamentals of Earthquake Engineering*. Englewood Cliffs, NJ: Prentice-Hall, 1971, p 422.

[6] PRITSKY, W. W. *Aluminum Construction Manual Specification for Aluminum Structures*. The Aluminum Association, 1982.⁵

2.1 Applicable Document in Preparation⁶

3. Definitions

acting stress. Maximum applied or expected stress in the material during normal operation of the apparatus of which it is a part, including the stresses caused by wind, seismic, or short-circuit loading, acting either independently or simultaneously as determined by the user.

allowable stress. The maximum stress permitted by applicable standards or codes, or both.

Class A component. Any component or system whose failure, malfunction, or need for repair prevents the proper operation of the substation during or after the design earthquake.

³ ASME publications are available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

⁴ ICBO publications are available from the International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, California 90601.

⁵ Aluminum Association publications are available from the Aluminum Association, 818 Connecticut Avenue NW, Washington, DC 20006.

⁶ When the following document is completed, approved and published, it becomes a part of this listing.

(1) IEEE Project C37.122 (in preparation) Recommended Practice for Gas-Insulated Substations.

Class B component. Any component or system whose failure, malfunction, or need for repair does not prevent the operation of the substation during or after the design earthquake.

component. The devices and equipment which are assembled at the erection site, or readily removed or accessed for maintenance, and which perform a function (for example, power circuit breakers, disconnect switches, relays, sensors).

damping. A dynamic property which indicates the ability of a structure to dissipate energy.

NOTE: The phenomenon of damping is represented by a quantity called the damping ratio which is a percent of critical damping. After being forced to deflect and allowed to vibrate freely, structures with zero damping vibrate indefinitely. Structures with critical damping return to their static or neutral position in the shortest time without oscillation.

design earthquake. The greatest earthquake postulated during the life of the substation for which the user wishes the substation to remain operational.

ductility factor. The ratio of the maximum displacement (ultimate) to the displacement which corresponds to initiation of the yielding.

maximum ground acceleration. The maximum value of acceleration input to the equipment during a given earthquake for a particular site.

natural frequency. The frequency(s) at which a body vibrates due to its own physical characteristics (mass, shape, boundary conditions, and elastic restoring forces brought into play) when the body is distorted and then released, while restrained or supported at specified points.

resonance. A dynamic condition which occurs when any input frequency of vibration coincides with one of the natural frequencies of the structure. In a plot of the response of the structure (acceleration, velocity, displacement) versus input frequency for a constant input, as the input frequency approaches one of the natural frequencies of the structure the response increases to a maximum value if damping is less than critical. The response of the structure at resonance may be much greater than the input, if the damping is low.

response spectrum. A plot of the maximum response of single-degree-of-freedom bodies of different natural frequencies, at a damping value expressed as a percent of critical damp-

ing, rigidly mounted on the surface of interest (that is, on the foundation for the foundation response spectrum or on the floor of a building for that floor's response spectrum) when that surface is subjected to a given earthquake motion as modified by intervening structures.

system. A group of components operating together to perform a function (for example, disconnect switch, support structure and foundation, relay protection system, and telemetering system).

time history. The record of acceleration, velocity or displacement as a function of time which the floor of a building or the ground experiences due to an earthquake.

zero period acceleration. The peak time history acceleration which can be determined from response spectra by the merging of response spectra, for all damping values, in the high-frequency range (usually above 30 Hz) in which no change of acceleration occurs with frequency.

4. Seismic Criteria

4.1 Seismic Information User Should Provide to Equipment Manufacturer

4.1.1 General. The user should provide information to the manufacturer that will adequately describe the seismic environment which the equipment will be expected to withstand. Any condition which may be of consequence during a seismic event should be described. However, the user should at least describe the maximum acceleration and response spectra or time history, as discussed in 4.1.2, 4.1.3, and 4.1.4.

The maximum vertical ground acceleration should be taken as 67% of the maximum horizontal design acceleration.

4.1.2 Maximum Acceleration. The maximum acceleration is the maximum value of acceleration input to the equipment during a given earthquake for a particular site. Typical design values of maximum acceleration range from 0.1 g (g is the acceleration due to gravity) to 0.5 g, with values over 0.5 g being required in some special instances. If the equipment is not mounted on the ground, the acceleration at the mounting location should be used.