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## IEEE 693 SEISMIC QUALIFICATION OF COMPOSITES FOR SUBSTATION HIGH-VOLTAGE EQUIPMENT

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### SUMMARY

This paper discusses research on the application of IEEE Standard 693 seismic qualification requirements for hollow-core composite insulators used on high-voltage instrument transformer substation equipment. The IEEE 693 qualification procedure of time history shake-table and static-pull tests as well as the acceptance criteria is evaluated. Failure modes for composite insulators are discussed. Experimental observations show that the acceptance criteria are invalid for qualifying hollow-core composites. The need for a static-pull test following vibration qualification tests is presented. The need for post-vibration-test measurement of damping is discussed. Changes to the IEEE standard and potential research are recommended.

### INTRODUCTION

IEEE Standard 693-1997, "IEEE Recommended Practice for Seismic Design of Substations" [1], is a major improvement in the way the power industry seismically qualifies substation high-voltage equipment. The standard has established discrete qualification levels with associated controlling response spectra, and well-defined qualification procedures and acceptance criteria. In addition to general procedures for analysis and testing, special procedures and criteria are developed for individual classes of equipment that reflect their unique characteristics and earthquake performance.

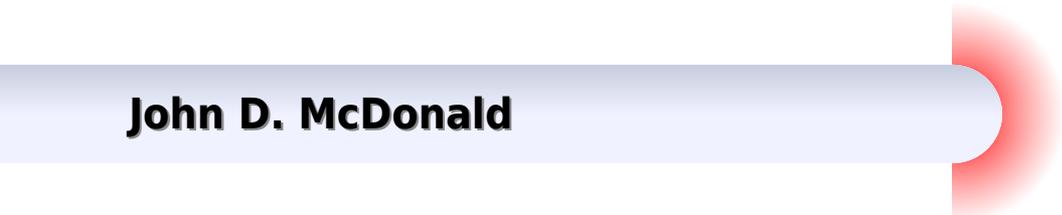
The standard provides two seismic qualification performance levels that are defined by excitation response spectra. Acceptance criteria are established so that equipment shake table-tests qualification need only be subjected to an excitation half of those defined by the performance response spectra. While not explicitly stated in the standard, it is the view of the authors that testing to half of the performance level requires that the failure modes of the equipment are understood and that associated critical variables, such as a strain, can be measured. The acceptance

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# Ieee 693 Seismic Qualification Of Composites For

**John D. McDonald**



## **Ieee 693 Seismic Qualification Of Composites For:**

**Electric Power Substations Engineering** John D. McDonald, 2016-04-19 Combining select chapters from Grigsby's standard setting *The Electric Power Engineering Handbook* with several chapters not found in the original work *Electric Power Substations Engineering* became widely popular for its comprehensive tutorial style treatment of the theory design analysis operation and protection of power substations For its *The Electric Power Engineering Handbook - Five Volume Set* Leonard L. Grigsby, 2018-12-14 *The Electric Power Engineering Handbook Third Edition* updates coverage of recent developments and rapid technological growth in crucial aspects of power systems including protection dynamics and stability operation and control With contributions from worldwide field leaders edited by L L Grigsby one of the world's most respected accomplished authorities in power engineering this reference includes chapters on Nonconventional Power Generation Conventional Power Generation Transmission Systems Distribution Systems Electric Power Utilization Power Quality Power System Analysis and Simulation Power System Transients Power System Planning Reliability Power Electronics Power System Protection Power System Dynamics and Stability Power System Operation and Control Content includes a simplified overview of advances in international standards practices and technologies such as small signal stability and power system oscillations power system stability controls and dynamic modeling of power systems Each book in this popular series supplies a high level of detail and more importantly a tutorial style of writing and use of photographs and graphics to help the reader understand the material This resource will help readers achieve safe economical high quality power delivery in a dynamic and demanding environment Volumes in the set K12642 *Electric Power Generation Transmission and Distribution Third Edition* ISBN 9781439856284 K12648 *Power Systems Third Edition* ISBN 9781439856338 K13917 *Power System Stability and Control Third Edition* 9781439883204 K12650 *Electric Power Substations Engineering Third Edition* 9781439856383 K12643 *Electric Power Transformer Engineering Third Edition* 9781439856291 **Seismic Evaluation of 550 KV Porcelain Transformer Bushings**, 1999 [Electric Power Substations Engineering, Third Edition](#) John D. McDonald, 2012-05-16 The use of electric power substations in generation transmission and distribution remains one of the most challenging and exciting areas of electric power engineering Recent technological developments have had a tremendous impact on all aspects of substation design and operation With 80% of its chapters completely revised and two brand new chapters on energy storage and Smart Grids *Electric Power Substations Engineering Third Edition* provides an extensive updated overview of substations serving as a reference and guide for both industry and academia Contributors have written each chapter with detailed design information for electric power engineering professionals and other engineering professionals e.g. mechanical civil who want an overview or specific information on this challenging and important area This book Emphasizes the practical application of the technology Includes extensive use of graphics and photographs to visually convey the book's concepts Provides applicable IEEE industry standards in each chapter Is written by

industry experts who have an average of 25 to 30 years of industry experience Presents a new chapter addressing the key role of the substation in Smart Grids Editor John McDonald and this very impressive group of contributors cover all aspects of substations from the initial concept through design automation and operation The book s chapters which delve into physical and cyber security commissioning and energy storage are written as tutorials and provide references for further reading and study As with the other volumes in the Electric Power Engineering Handbook series this book supplies a high level of detail and more importantly a tutorial style of writing and use of photographs and graphics to help the reader understand the material Several chapter authors are members of the IEEE Power Energy Society PES Substations Committee and are the actual experts who are developing the standards that govern all aspects of substations As a result this book contains the most recent technological developments in industry practice and standards Watch John D McDonald talk about his book A volume in the Electric Power Engineering Handbook Third Edition Other volumes in the set K12642 Electric Power Generation Transmission and Distribution Third Edition ISBN 9781439856284 K12648 Power Systems Third Edition ISBN 9781439856338 K13917 Power System Stability and Control Third Edition ISBN 9781439883204 K12643 Electric Power Transformer Engineering Third Edition ISBN 9781439856291 **Report** ,1999 *IEEE Standards* Institute of Electrical and Electronics Engineers,1997 **Optimizing Post-earthquake Lifeline System Reliability** William M. Elliott,Peter W. McDonough,1999 TCLEE Monograph 16 presents more than 100 papers from the Fifth U S Conference on Lifeline Earthquake Engineering held in Seattle Washington August 12 14 1999 *Transmission Grid Research* Merwin Brown,California Institute for Energy and Environment,2012 *Quick Reference to IEEE Standards* ,1986 A complete index of all terms in IEEE Standards and ANSI Standards published by IEEE together with tables of contents of all the documents indexed Cover *Thomas Register of American Manufacturers* ,2002 This basic source for identification of U S manufacturers is arranged by product in a large multi volume set Includes Products services Company profiles and Catalog file *Thomas Register of American Manufacturers and Thomas Register Catalog File* ,2002 Vols for 1970 71 includes manufacturers catalogs **Index to IEEE Publications** Institute of Electrical and Electronics Engineers,1976 Issues for 1973 cover the entire IEEE technical literature *Applied Mechanics Reviews* ,1987 **Index and Directory of U.S. Industry Standards** ,1985 **Science Citation Index** ,1994 Vols for 1964 have guides and journal lists *EVALUATION AND PROTECTION OF HIGH VOLTAGE ELECTRICAL EQUIPMENT AGAINST SEVERE SHOCK AND VIBRATIONS* Dohwan Kong,2010 In recent moderate and strong seismic events it was demonstrated that parts of the electrical power system are vulnerable to damage and their performance is strongly influenced by specific equipment design and installation practice The damage or malfunction of electrical substations which plays a key role in the distribution and transmission of electricity may bring severe grid failures in large areas and substantial indirect financial losses much larger than the direct recovery costs of the damaged equipment Shinozuka et al 2004 Moreover the absence of electricity may delay response and recovery from

natural disasters such as earthquakes Thus in order to build standard methods of providing and validating the seismic capability of electrical substation equipment to sustain the high demands detailed testing and analysis methods are needed Although current standards specify the required capacities of various types of substation equipment and the method for evaluating these capacities discrepancies between the required capacities and the real behavior observed in seismic events were questioned by recent research studies Electrical substation equipment includes a variety of complex components made of multiple mechanical parts and structures which when subjected to earthquakes may fail and impair the electrical functionality Among those some of the most complex and vulnerable components are i disconnect switches and ii high power transformers Each of these components has vulnerable parts which should be studied evaluated and possibly protected in order to ensure continuous operation after earthquakes This dissertation focuses on the two systems indicated above A disconnect switch used in substations of large electrical grids is an important component that supports the functionality of the electrical network Such a switch is a combination of a support structure and the switching mechanism which in turn is made of fixed and moving metal parts and of ceramic or composite electrical insulators In order to determine if this equipment is acceptable in seismic areas the static and dynamic characteristics of these high voltage three phases disconnect switches and their capacity to withstand severe vibrations testing has to be performed Due to the complexity of such systems and uncertainties in the construction and behavior of components such determination cannot be done computationally In an attempt to determine contributions of components to the global response of the disconnect switch DS systems this work proceeds with a methodical experimental and computational study Tests to find the characteristics of each component were performed first followed by tests of various subassemblies Moreover the entire assembly was also tested while observing the contributions of the individual components and sub assemblies When weak components were identified a solution for protecting the components through modification of the response of the global system was attempted The test results and the numerical evaluations showed several important characteristics in the behavior of the disconnect switches and issues in their acceptance testing qualifications The adequacy and acceptance of transformers and transformer bushings is of great concern in the electrical industry The current practice such as the IEEE 693 2005 recommends the following about the qualification tests of a transformer bushing i using a rigid frame to hold the bushing on a shake table instead of using a real transformer tank and ii doubling input ground motions to consider the amplification of the ground motion caused by the flexibility of the transformer tank The rigid frame lacks the capability to simulate the dominant effects of the local connectivity of the bushing to the transformer s cover while the base motion recommended by the current code underestimates the effects of the influence of the tank walls and cover plate on the motion transmitted to the bushing at its connection to the tank While a bushing is mounted on the roof cover of a transformer tank the excitation transmitted to the bushing is not identical to the ground motion below the transformer tank The roof motion is amplified or attenuated differently in the horizontal and

vertical directions due to the dynamics of the tank This study identifies the issues related to the acceptance testing and proposes designs develops and evaluates experimentally and numerically a support frame simulating transformer behavior Due to limitations in reproducing simulated earthquake ground motions seismic qualification testing is often limited to lower levels of shaking In this study the possibility of using a modulated sine sweep that can be implemented in smaller laboratories as an input base motion for qualification purposes is investigated The sine sweep proposed is modulated to match an arbitrary required response spectrum for electrical equipment such as required by IEEE 693 RRS In addition to the existing methods to identify system frequencies and damping values specified in testing standards an alternative method i e a table impulse test is developed and evaluated by analyzing testing results A table impulse test can share most of advantages which can be found from the existing resonant frequency search test methods while each existing method shares only one or some of those advantages This dissertation focuses on the evaluation of current practice and proposes develops and verifies experimentally and numerically where feasible new techniques of evaluation and improvement of the adequacy of electrical equipment

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