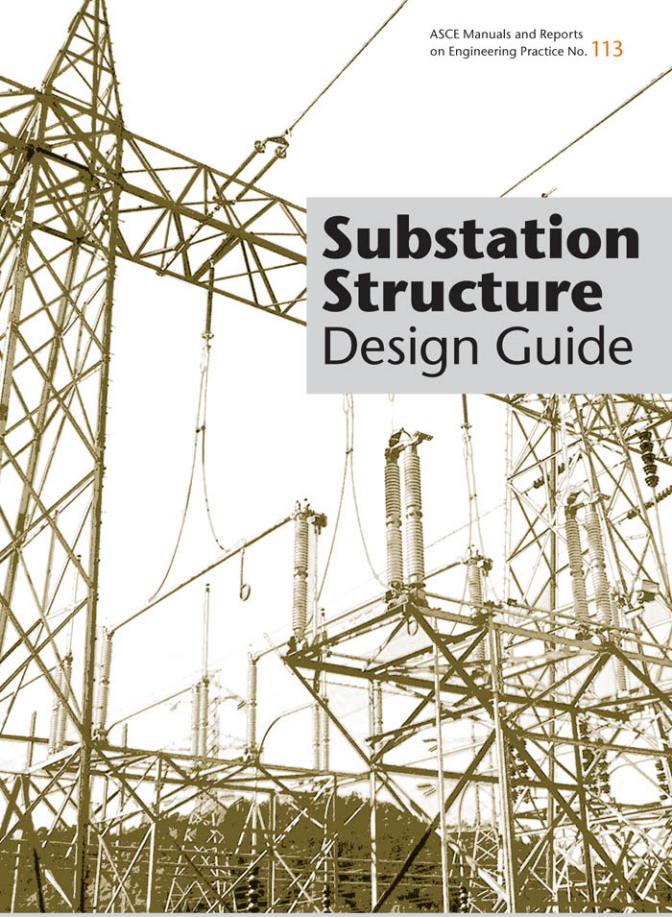
ASCE Manuals and Reports
on Engineering Practice No. 113

Substation Structure Design Guide



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ASCE Manuals and Reports on Engineering Practice No. 113

Substation Structure Design Guide

Prepared by
the Subcommittee on the Design of Substation Structures of the
Committee on Electrical Transmission Structures of the
Structural Engineering Institute of the
American Society of Civil Engineers

Edited by
Leon Kempner, Jr.

ASCE American Society of Civil Engineers

SEI Structural Engineering Institute of the American Society of Civil Engineers

Library of Congress Cataloging-in-Publication Data

Substation structure design guide : ASCE manuals and reports on engineering practice no. 113 / Prepared by the Subcommittee on the Design of Substation Structures of the Structural Division of the American Society of Civil Engineers ; edited by Leon Kempner.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-0-7844-0935-0 (alk. paper)
ISBN-10: 0-7844-0935-8 (alk. paper)
1. Structural design–Handbooks, manuals, etc. I. Kempner, Leon. II. American Society of Civil Engineers. Subcommittee on the Design of Substation Structures .
TA658.3.S83 2007
621.31'26–dc22

2007016342

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191

www.pubs.asce.org

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ISBN 13: 978-0-7844-0935-0
ISBN 10: 0-7844-0935-8
Manufactured in the United States of America.

15 14 13 12 11 10 09 08 07 1 2 3 4 5

MANUALS AND REPORTS ON ENGINEERING PRACTICE

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In February 1962 (and revised in April 1982) the Board of Direction voted to establish a series entitled "Manuals and Reports on Engineering Practice," to include the Manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such Manual or Report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past Manuals. Numbering would be consecutive and would be a continuation of present Manual numbers. In some cases of reports of joint committees, bypassing of Journal publications may be authorized.

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71	Agricultural Salinity Assessment and Management
72	Design of Steel Transmission Pole Structures
73	Quality in the Constructed Project: A Guide for Owners, Designers, and Constructors
74	Guidelines for Electrical Transmission Line Structural Loading
76	Design of Municipal Wastewater Treatment Plants
77	Design and Construction of Urban Stormwater Management Systems
78	Structural Fire Protection
79	Steel Penstocks
80	Ship Channel Design
81	Guidelines for Cloud Seeding to Augment Precipitation
82	Odor Control in Wastewater Treatment Plants
83	Environmental Site Investigation
84	Mechanical Connections in Wood Structures
85	Quality of Ground Water
86	Operation and Maintenance of Ground Water Facilities
87	Urban Runoff Quality Manual
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89	Pipeline Crossings
90	Guide to Structural Optimization
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101	Underwater Investigations
102	Design Guide for FRP Composite Connections
103	Guide to Hiring and Retaining Great Civil Engineers
104	Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures
105	Animal Waste Containment in Lagoons
106	Horizontal Auger Boring Projects
107	Ship Channel Design and Operation
108	Pipeline Design for Installation by Horizontal Directional Drilling
109	Biological Nutrient Removal (BNR) Operation in Wastewater Treatment Plants
110	Sedimentation Engineering: Processes, Measurements, Modeling, and Practice
111	Reliability-Based Design of Utility Pole Structures
112	Pipe Bursting Projects
113	Substation Structure Design Guide

CONTENTS

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PREFACE

The Subcommittee on the Design of Substation Structures of the Committee on Electrical Transmission Structures of the Structural Engineering Institute of ASCE developed this manual. The subcommittee membership represented utilities, manufacturers, consulting firms, academia, research, and general interest. The combined expertise of the subcommittee members contributed to make this a valuable substation structure design guide for the utility industry.

The primary purpose of this manual is to document electrical substation structural engineering practice and to give guidance and recommendations for the design of outdoor electrical substation structures. The guide presents a review of structure types and typical electrical equipment. Guidelines for analysis methods, structure loads, deflection criteria, member and connection design, structure testing, quality control, quality assurance, connections used in foundations, detailing, fabrication, construction, and maintenance issues are presented. The recommendations presented herein are based on the professional experience of the subcommittee members, and although the subject matter of this manual has been thoroughly researched, its application should be based on sound engineering judgment.

The subcommittee wishes to thank the Peer Review Committee for their assistance and contributions to this document.

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The subcommittee thanks all the individuals who have contributed to the completion of this manual. Without their contributions, guidance, and dedication, this manual would not have been published. The following individuals have contributed to this manual, either as past subcommittee members or as corresponding members:

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Tom Teevin
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This edition of the manual is dedicated to Richard Byrne, James Kennedy, and Jake Kramer. These individuals were instrumental in initiating, contributing, and mentoring this subcommittee's activity.

ACKNOWLEDGMENTS

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CHAPTER 1
INTRODUCTION

The purpose of this manual is to provide a comprehensive resource document for the structural design of outdoor electrical substation structures. The recommendations herein apply to substation structures that support electrical equipment and rigid bus and other conductors. The electrical equipment can be of significant weight and have attachments of porcelain or composite components. Knowledge of the operational requirements of the equipment being supported is required and discussed. Deflection limits for operability can control the design of a substation structure.

Specific guidelines for structural loads, deflection limits, analysis, design, fabrication, maintenance, and construction of substation structures are recommended. Guidelines for the design of the structure connections to their foundations are presented. This manual addresses steel, concrete, wood, and aluminum used for the design of substation structures. Design equations are provided when references to existing structural design standards and codes (e.g., American Concrete Institute, American Institute of Steel Construction, American Institute of Timber Construction, and ASCE) are not appropriate or convenient. Some figures (i.e., maps and graphs) are shown for information; the user of these figures can consult the reference for more detail.

The utility industry uses both the allowable stress design (ASD) and ultimate strength design (USD) methods. *Allowable stress design* is a method of proportioning structural members such that elastically computed stresses produced in the members by nominal loads do not exceed specified allowable stresses (also called working stress design). *Ultimate strength design* is a method of proportioning structural members such that the computed forces produced in the members by the factored loads do not

exceed the member design strength (also called load and resistance factored design, LRFD).

A significant issue discussed during the development of this manual was the direction it should take with respect to design of substation structures using either ASD or USD concepts. Because of the diversity in the utility industry with respect to the use of these two concepts, it was decided that both ASD and USD would be addressed. USD is the preferred method for substation structures.

Guidelines for the development of substation structure loads for wind, ice, seismic, short circuit, line tensions, equipment reactions, construction, maintenance, and regulatory codes (e.g., National Electric Safety Code (NESC 2007), General Order 95 (2006), and ASCE) are recommended. The specific recommendations are based on structure type, such as dead-end structures, disconnect switch supports, and bus supports. Recommended load factors and load combinations are presented.

The seismic load section complements IEEE 693 (2005). IEEE 693 (2005) addresses electrical equipment and its first support requirements. First support could be a pedestal for a current transformer (CT) or a support beam for a capacitor bank. This manual will reference IEEE 693 (2005) and provide seismic requirements for structures not covered by that reference.

Substation structures and the electrical equipment they support should be considered as a system. Excessive structure movement could cause the electrical equipment to experience mechanical damage, operational difficulties, and electrical faults. Recommended deflection limits and structure classes are defined in Chapter 4 of this manual.

Analysis techniques and structural modeling concepts as they relate to substation structures are discussed in Chapter 5. Both static and dynamic analyses are covered. Guidelines are given for selecting the appropriate analysis method for different structural behavior, such as large versus small displacements.

This manual references other appropriate design documents for design equations and in general notes only exceptions to the referenced documents.

Recommendations on when it is appropriate to test a unique substation structure design concept or perform individual component testing are given. Requirements for seismic testing are covered in IEEE 693 (2005).

Guidelines for quality control and quality assurance programs for substation structures are presented in Chapter 8. References are given to the appropriate industry documents that address steel, aluminum, concrete, and wood structures.

Foundation design is not presented in this manual. However, the following information should be considered for substation structure foundation design. A variety of structure types are used in electrical

substations, and these structures have a wide range of ground line reactions. Typical substation structure foundation types can be slabs on grade, spread footings, drilled shafts, and piling with and without pile caps. Substation foundations should be designed such that they do not adversely affect the deflection criteria recommended herein. The effects of soil–structure interaction from earthquakes are important and do exist, especially for large loads, such as that caused by power transformers. Foundation design should, where applicable, consider the effect of ground frost heave and the effect of buoyancy of the groundwater table. Foundations in substations should be designed according to accepted practice, the same as foundations designed for other structures. IEEE 691 (2001) is one source of information regarding the design of utility-type structure foundations.

The design of substation structure anchorage to the foundation is presented in Chapter 7. Many different types of anchorages are used to connect substation structures to their foundations. The most common anchorage is anchor bolts cast in concrete. This manual gives design recommendations for this type of anchorage. Special design considerations for seismic anchorage are covered.

The application of this manual is limited to the structural design and analysis of new electrical substation facilities. Any modification to existing structures that results in structural load variation or structural response behavior alteration should be in compliance with (a) the code or standard that was in effect at the time of the original installation, or (b) the code or standard in effect in a subsequent modification to which the structure has been previously brought into compliance, or (c) the recommendations of this manual.