

IEEE 3000
STANDARDS COLLECTION™

IEEE 3006 STANDARDS:
POWER SYSTEMS RELIABILITY

Historical Reliability Data for IEEE 3006 Standards: Power Systems Reliability



IEEE STANDARDS ASSOCIATION



**IEEE 3000 Standards Collection™
for Industrial & Commercial Power Systems**

**Historical Reliability Data for
IEEE 3006 Standards:
Power Systems Reliability**

Compiled by the

**Technical Books Coordinating Committee
of the
IEEE Industry Applications Society**

Abstract: Reliability data gathered from equipment reliability surveys and analyses over a period of 35 years or more is summarized in this collection. Equipment surveys conducted prior to 1976, detailed reports on the surveys and data collection efforts, and extensive lists of references on equipment reliability are presented. The collection provides the analyst with options for determining reliability parameters for older electrical systems.

Keywords: commercial power systems, electrical interruptions, IEEE Gold Book™ annex, historical reliability data, IEEE 3006, industrial power systems, outage data, power systems reliability, reliability analysis, reliability survey

This IEEE-SA publication is not a consensus document. Information contained in this work has been obtained from sources believed to be reliable and reviewed by credible members of IEEE Technical Societies, Standards Committees, and/or Working Groups, and/or relevant technical organizations. Neither the IEEE nor its authors guarantees the accuracy or completeness of any information published herein, and neither the IEEE nor its authors shall be responsible for any errors, omissions, or damages arising out of the use of this information.

Likewise, while the author and publisher believe that the information and guidance given in this work serve as an enhancement to users, all parties must rely upon their own skill and judgement when making use of it. Neither the author nor the publisher assumes any liability to anyone for any loss or damage caused by any error or omission in the work, whether such error or omission is the result of negligence or any other cause. Any and all such liability is disclaimed.

This work is published with the understanding that the IEEE and its authors are supplying information through this publication, not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought. The IEEE is not responsible for the statements and opinions advanced in the publication.

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2012 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 9 November 2012. Printed in the United States of America.

IEEE and Color Books are registered trademarks in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

National Electrical Code, NEC, and NFPA 70 are registered trademarks in the U.S. Patent & Trademark Office, owned by the National Fire Protection Association.

Mission critical facilities is a registered trademark of EYP Mission Critical Facilities, Inc.

Print: ISBN 978-0-7381-7563-8 STDVAPD95897
PDF: ISBN 978-0-7381-7562-1 STDVA95897

IEEE prohibits discrimination, harassment and bullying. For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>. No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Notice to users

Laws and regulations

Users of IEEE-SA documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE-SA document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

Photocopies

Authorization to photocopy portions of any individual document for internal or personal use is granted by The Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual document for educational classroom use can also be obtained through the Copyright Clearance Center.

Foreword

Compiled in this collection of historical reliability data is invaluable information supporting the planning and design of industrial and commercial electric power distribution systems. It is a compilation of historical survey information collected through the efforts of Don Koval and Charles Heising over a period of approximately 35 years. This is a tribute to them and all of the contributors that made IEEE Std 493™ (*IEEE Gold Book™*) one of the best in what was the IEEE Color Book® series.

This collection summarizes the reliability information collected from equipment reliability surveys over a period of 35 years or more. It consists of equipment surveys conducted prior to 1976, detailed reports on the surveys and data collection efforts, and extensive lists of references on equipment reliability. Selected reliability and availability numeric from the survey efforts are also presented in this document.

This document provides the analyst with options for determining reliability parameters for older electrical systems. Data not found anywhere else is the cornerstone of this document, with some surveys spanning many years. In addition, there is utility numeric critical to facility assessments that identifies available power.

Robert G. Arno, *Senior Member of IEEE*

*This collection is respectfully dedicated to Don Koval and Charles Heising,
who devoted countless hours to compiling this data for the benefit of the industry.*

Contents

Report on Reliability Survey of Industrial Plants—Parts I, II, and III	1
Report on Reliability Survey of Industrial Plants—Parts IV, V, and VI.....	61
Cost of Electrical Interruptions in Commercial Buildings	87
Reliability of Electric Utility Supplies to Industrial Plants	95
Report of Switchgear Bus Reliability Survey of Industrial Plants and Commercial Buildings	100
Working Group Procedure for Conducting an Equipment Reliability Survey	109
Report of Transformer Reliability Survey—Industrial Plants and Commercial Buildings.....	114
Report of Large Motor Reliability Survey of Industrial and Commercial Installations Parts I, II, and III.....	124
Reliability Study of Cable, Terminations, and Splices by Electric Utilities in the Northwest.....	151
Summary of CIGRE 13.06 Working Group World Wide Reliability and Maintenance Cost Data on High Voltage Circuit Breakers above 63 kV.....	161
Report of Circuit Breaker Reliability Survey of Industrial and Commercial Installations	170
Reliability Survey of 600 to 1800 kW Diesel and Gas-Turbine Generating Units	187
Reliability/Availability Guarantees of Gas Turbines and Combined Cycle Generating Units	203
Transmission Line and Equipment Outage Data	221
Interruption Costs, Consumer Satisfaction, and Expectations for Service Reliability	258
Survey Results of Low-Voltage Breakers as Found During Maintenance Testing.....	266
Survey of Reliability and Availability Information for Power Distribution, Power Generation, and HVAC Components for Commercial, Industrial, and Utility Installations	271

Report on Reliability Survey of Industrial Plants

Part I

Reliability of Electrical Equipment

Part II

**Cost of Power Outages, Plant Restart Time, Critical Service Loss
Duration Time, and Type of Loads Lost Versus Time of Power Outages**

Part III

**Causes and Types of Failures of Electrical Equipment,
the Methods of Repair, and the Urgency of Repair**

By

**Reliability Subcommittee
Industrial and Commercial Power Systems Committee
IEEE Industry Applications Society**

W. H. Dickinson, *Chair*

P. E. Gannon
M. D. Harris

C. R. Heising
D. W. McWilliams
R. W. Parisian

A. D. Patton
W. J. Pearce

**Industrial and Commercial Power Systems Technical Conference
Institute of Electrical and Electronics Engineers, Inc.
Atlanta, Georgia
May 13–16, 1973**

Published by
IEEE Transactions on Industry Applications
March/April 1974

Report on Reliability Survey of Industrial Plants, Part I: Reliability of Electrical Equipment

IEEE COMMITTEE REPORT

Abstract—An IEEE sponsored survey of electrical equipment reliability in industrial plants was completed during 1972. The results are reported from this survey which included a total of 1982 equipment failures that were reported by 30 companies covering 68 plants in nine industries in the United States and Canada.

INTRODUCTION

A KNOWLEDGE of the reliability of electrical equipment is an important consideration in the design of power distribution systems for industrial plants. It is possible to make quantitative reliability comparisons between alternative designs of new systems and then use this information in cost-reliability tradeoff studies to determine which type of power distribution systems to use [1]–[10]. The cost of power outages at the various plant locations can be factored into the decision as to which type of power distribution system to use. These decisions can then be based upon total owning cost over the useful life of the equipment rather than first cost.

In 1969 a Reliability Working Group was formed under the Industrial Plants Power Systems Subcommittee, Industrial and Commercial Power Systems Committee. In 1972 the activity was changed to a Reliability Subcommittee under the same Committee. One of the major activities of the Reliability Working Group and the Reliability Subcommittee has been to conduct a survey of equipment reliability in industrial plants. This survey was conducted during the latter half of 1971 and the early part of 1972 and attempted to update a similar survey [11] which had been conducted eleven years ago. The results from the present survey contain data on failure rate and average downtime per failure for 74 equipment categories. The Reliability Subcommittee also felt that additional information was needed in the present survey beyond what was collected twelve years ago. Some of the additional information is the following:

- 1) cost of power outages of industrial plants;
- 2) plant restart time;
- 3) critical service loss duration time;
- 4) type of loads lost versus time of power outages;
- 5) repair or replacement time data;

Paper TOD-73-158, approved by the Industrial and Commercial Power Systems Committee of the IEEE Industry Applications Society for presentation at the 1973 Industrial and Commercial Power Systems Technical Conference, Atlanta, Ga., May 13-16. Manuscript released for publication November 5, 1973.

Members of the Reliability Subcommittee of the IEEE Industrial and Commercial Power Systems Committee are W. H. Dickinson, *Chairman*, P. E. Gannon, M. D. Harris, C. R. Heising, D. W. McWilliams, R. W. Parsian, A. D. Patton, and W. J. Pearce.

- 6) repair urgency information;
- 7) causes and types of failures;
- 8) maintenance data and policies.

It is not practical to publish all the results contained in the survey in a single paper. They will be presented in six separate parts. The first three parts are published at this time

- Part 1: Reliability of Electrical Equipment;
- Part 2: Cost of Power Outages, Plant Restart Time, Critical Service Loss Duration Time, and Type of Loads Lost Versus Time of Power Outages [11];
- Part 3: Causes and Types of Failures, Methods of Repair, and Urgency of Repair [12].

A major part of the data in these three papers are presented in summary form. It is expected that the additional three papers will be presented at a later date and will contain further in-depth information where questions have been raised to point out the need for such data.

SURVEY FORM

The survey form is shown in Appendix A. Three types of cards were used for reporting the information.

Card type 1 asks for data on plant identification and other general plant information.

Card type 2 asks for data on a specific equipment class, including the total number of installed units, on their failure experience, on maintenance practices, and on estimated repair times of failed equipment.

Card type 3 asks for data on each individual failure reported on a card type 2.

It was necessary to provide definitions for "failure" and "repair time."

A *failure* is defined as any trouble with a power system component that causes any of the following to occur:

- 1) partial or complete plant shutdown, or below-standard plant operation;
- 2) unacceptable performance of user's equipment;
- 3) operation of the electrical protective relaying or emergency operation of the plant electrical system;
- 4) de-energization of any electric circuit or equipment.

A failure on a public utility supply system may cause the user to have either 1) a power interruption or loss of service, or 2) a deviation from normal voltage or frequency of sufficient magnitude or duration to disrupt plant production. A failure on an in-plant component causes a forced outage of the compo-