

IEEE Std 3001.2™-2017

Recommended Practice
for Evaluating the Electrical
Service Requirements of
Industrial and Commercial
Power Systems



IEEE STANDARDS ASSOCIATION

IEEE Recommended Practice for Evaluating the Electrical Service Requirements of Industrial and Commercial Power Systems

Sponsor

Technical Books Coordinating Committee
of the
IEEE Industry Applications Society

Approved 6 December 2017

IEEE-SA Standards Board

Abstract: Commercial, institutional, and industrial design of electrical services, interconnecting with a utility distribution or transmission system is explored. The electrical system information needed by the designer concerning the utility's system characteristics, and the electrical load information needed by the utility to design a satisfactory electrical interface between the serving utility and the premise electrical distribution system is considered.

Keywords: electric rates, IEEE 3001.2, service, service entrance, substation, utility metering, utility billing, vaults

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

Copyright © 2017 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 10 May 2018. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-1-5044-4513-9 STD22890
Print: ISBN 978-1-5044-4514-6 STDPD22890

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.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (“IEEE-SA”) Standards Board. IEEE (“the Institute”) develops its standards through a consensus development process, approved by the American National Standards Institute (“ANSI”), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards 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

IEEE draft and approved standards are copyrighted by IEEE under US and international copyright laws. They are made available by IEEE and are adopted 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 these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, 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 standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every 10 years. When a document is more than 10 years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at <http://ieeexplore.ieee.org/xpl/standards.jsp> or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at <http://standards.ieee.org>.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this IEEE recommended practice was completed, the Power System Design Editorial Working Group had the following membership:

Gary H. Fox, *Chair*

Robert Arno
Neal Dowling
Nehad El-Sherif

Barry Hornberger
Duane Leschert

Dennis K. Neitzel
Amol Pathak
Marcelo Valdes

The following members of the individual balloting committee voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

Frank Basciano
Sirak Belayneh
Frederick Brockhurst
Gustavo Brunello
William Byrd
Paul Cardinal
Kurt Clemente
Glenn Davis
Davide De Luca
Neal Dowling
Gary Fox
Randall Groves
Chris Heron
Werner Hoelzl
Robert Hoerauf
Laszlo Kadar
Gael Kennedy
Yuri Khersonsky
Jim Kulchisky

Saumen Kundu
Marc Lacroix
Benjamin Lanz
Wei-Jen Lee
Duane Leschert
John Mcalhaney Jr.
William McBride
John McClelland
Massimo Mitolo
Daleep Mohla
Jerry Murphy
Daniel Neeser
Dennis K. Neitzel
Michael Newman
Joe Nims
Gearold O. H. Eidhin
T. W. Olsen
Lorraine Padden
Antony Parsons
Jim Phillips

Louie Powell
Iulian Profir
Moises Ramos
Charles Rogers
Vincent Saporita
Bartien Sayogo
Ted Schoenberg
Robert Seitz
Nikunj Shah
Jeremy Smith
Jerry Smith
Gary Smullin
Wayne Stec
K. Stump
David Tepen
Marcelo Valdes
Kenneth White
James Wolfe
Jian Yu

When the IEEE-SA Standards Board approved this recommended practice on 6 December 2017, it had the following membership:

Jean-Philippe Faure, *Chair* **Gary Hoffman, *Vice Chair*** **John D. Kulick, *Past Chair*** **Konstantinos Karachalios, *Secretary***

Chuck Adams
Masayuki Ariyoshi
Ted Burse
Stephen Dukes
Doug Edwards
J. Travis Griffith
Michael Janezic

Thomas Koshy
Joseph L. Koepfinger*
Kevin Lu
Daleep Mohla
Damir Novosel
Ronald C. Petersen
Annette D. Reilly

Robby Robson
Dorothy Stanley
Adrian Stephens
Mehmet Ulema
Phil Wennblom
Howard Wolfman
Yu Yuan

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 3001.2™-2017, IEEE Recommended Practice for Evaluating the Electrical Service Requirements of Industrial and Commercial Power Systems.

IEEE 3000 Standards Collection™

This recommended practice was developed by the Technical Books Coordinating Committee of the Industrial and Commercial Power Systems Department of the Industry Applications Society, as part of a project to repackage IEEE's popular series of IEEE Color Books®. The goal of this project is to speed up the revision process, eliminate duplicate material, and facilitate use of modern publishing and distribution technologies.

When this project is completed, the technical material included in the 13 Color Books will be included in a series of new standards—the most significant of which will be a new book, IEEE Standard 3000™, IEEE Recommended Practice for the Engineering of Industrial and Commercial Power Systems. The new standard will cover the fundamentals of planning, design, analysis, construction, installation, start-up, operation, and maintenance of electrical systems in industrial and commercial facilities. Approximately 60 additional dot standards, organized into the following categories, will provide in-depth treatment of many of the topics introduced by IEEE Std 3000™:

- Power Systems Design (3001 series)
- Power Systems Analysis (3002 series)
- Power Systems Grounding (3003 series)
- Protection and Coordination (3004 series)
- Emergency, Standby Power, and Energy Management Systems (3005 series)
- Power Systems Reliability (3006 series)
- Power Systems Maintenance, Operations, and Safety (3007 series)

In many cases, the material in a “dot” standard comes from a particular chapter of a particular color book. In other cases, material from several color books has been combined into a new “dot” standard.

The material in this recommended practice largely comes from Chapter 2 and Chapter 15 of the *IEEE Red Book*™, IEEE Std 141™-1993, Recommended Practice for Electric Power Distribution in Industrial Plants, and Chapter 4 and Chapter 7 of the *IEEE Gray Book*™, IEEE Std 241™-1990.

IEEE Std 3001.2

This publication provides a recommended practice for the electrical design of commercial and industrial facilities. It is likely to be of greatest value to the power-oriented engineer with limited commercial or industrial plant experience. It can also be an aid to all engineers responsible for the electrical design of commercial and industrial facilities. However, it is not intended as a replacement for the many excellent engineering texts and handbooks commonly in use, nor is it detailed enough to be a design manual. It should be considered a guide and general reference on electrical design for commercial and industrial facilities.

Tables, charts, and other information that have been extracted from codes, standards, and other technical literature are included in this publication. Their inclusion is for illustrative purposes; where technical accuracy is important, the latest version of the referenced document should be consulted to assure use of complete, up-to-date, and accurate information.

Contents

1. Scope.....	10
2. Normative references	10
3. Common relationships with electric utilities	11
4. Planning for utility service	11
4.1 Introduction	11
4.2 Utility/designer communication	12
4.3 Service availability	12
4.4 Facility load information	15
4.5 Information from the utility	16
4.6 Interrelated utility and project factors that influence design	19
5. Electric rates.....	20
5.1 Demand and fixed charges.....	20
5.2 Energy and variable charges	20
5.3 Power factor credits and penalties	21
6. Electric utility metering and billing.....	21
6.1 Introduction	21
6.2 Metering by type of premises	22
6.3 Metering by service voltage characteristics	22
6.4 Meter location.....	22
6.5 Meter mounting, control, and associated equipment	23
6.6 Metering equipment guidelines and types	24
6.7 Metering for energy conservation.....	27
6.8 Utility billing	27
7. Distribution circuit arrangements.....	29
7.1 Introduction	29
7.2 Network systems	29
7.3 Small commercial buildings	29
7.4 Medium and large commercial buildings.....	29
7.5 Large industrial facilities	30
7.6 Medium-voltage distribution.....	30
7.7 Multiple services	30
7.8 Multiple tenants.....	30
8. Incoming lines and service laterals	30
8.1 Introduction	30
8.2 Overhead service	31
8.3 Underground service	33
8.4 Service entrance conductors within a building	34
9. Service entrance installations	35
9.1 Introduction	35
9.2 Number of services.....	35
9.3 Physical arrangement	36
9.4 Service design considerations.....	36
9.5 Medium-voltage services	38
9.6 Vaults and pads for service equipment.....	39
9.7 Network vaults for high-rise buildings	41

9.8 Service rooms and electrical closets	44
10. Large services.....	45
10.1 Introduction	45
10.2 Purpose.....	45
10.3 Substation justification	46
10.4 Development stages.....	46
10.5 Project participants.....	47
10.6 Planning stage	47
10.7 Design stage	58
10.8 Construction stage	66
Annex A (informative) Bibliography.....	70

IEEE Recommended Practice for Evaluating the Electrical Service Requirements of Industrial and Commercial Power Systems

1. Scope

This recommended practice explores commercial, institutional, and industrial design of electrical services, interconnecting with a utility distribution or transmission system. Close coordination between the facility electrical designer and the serving utility are critical for a successful service connection. This recommended practice considers the electrical system information needed by the designer concerning the utility's system characteristics and the electrical load information needed by the utility to design a satisfactory electrical interface between the serving utility and the premise electrical distribution system. It describes various ways to take power from the serving utility. It also covers the specific requirements for utility metering on service entrance equipment, as well as service equipment rooms, vaults, and pads.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Accredited Standards Committee C2™, National Electrical Safety Code® (NESC®).

IEC 61936-1-Ed.1.0, Power installations exceeding 1 kV ac—Part 1: Common Rules.¹

IEEE Std 80™, IEEE Guide for Safety in AC Substation Grounding.^{2,3}

IEEE Std 142™, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (*IEEE Green Book™*).

IEEE Std 693™, IEEE Recommended Practice for Seismic Design of Substations.

¹IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

²The IEEE standards or products referred to in [Clause 2](#) are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

³IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

IEEE Std 979™, IEEE Guide for Substation Fire Protection.

IEEE Std 980™, IEEE Guide for Containment and Control of Oil Spills in Substations.

IEEE Std 998™, IEEE Guide for Direct Lightning Stroke Shielding of Substations.

IEEE Std 1127™, IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility.

IEEE Std 1402™, IEEE Guide for Electric Power Substation Physical and Electronic Security.

NFPA 70®, National Electrical Code®(NEC®).⁴

3. Common relationships with electric utilities

The most common relationship that exists between the industrial or commercial facility and a connecting electric utility is that of a seller and buyer. That is, the electric utility supplies electric energy to the facility based on a rate typically regulated by a state agency as the utility will typically have a monopoly over serving a given geographic area. Considering this, the industrial or commercial user may be referred to as the *customer*. The relationship between a utility and its customer has become more complex based on the following developments.

- Wholesale power agreements that allow a user to purchase energy from entities other than the connecting utility. The connecting utility is not the direct seller of energy. However, the connecting utility will usually still be compensated for the use of their distribution system through *wheeling charges* that are added onto the user's monthly energy invoice.
- Community Choice Aggregation programs that allow users within the geographic boundaries of the program to secure alternative energy supply agreements by working in aggregate, typically through a city or county agency.
- The capability to generate power onsite, typically through cogeneration or renewable energy sources such as wind turbines or photovoltaic panels. Diesel engine or gas turbine sources may be used. The onsite generation may simply reduce the overall facility demand, or the user may be permitted to export power when the user's onsite source capacity is greater than the user's own load demand. The utility should be consulted to determine whether they are willing to accept any exported power, and any special requirements they have for users who install onsite power sources that may be connected to the utility distribution system.

4. Planning for utility service

4.1 Introduction

It is the responsibility of the engineer to understand the serving utility's electric service requirements and service tariffs to develop an efficient and economical means of receiving electric power and distributing it to each area to be served. This function can be carried out in many ways. Selection of system arrangements, components, and voltages should be engineered to function reliably and safely, and to deliver the power at correct voltages without hazard to personnel or the facility.

⁴NFPA publications are published by the National Fire Protection Association (<http://www.nfpa.org/>).

4.2 Utility/designer communication

Each utility differs in its service policies and requirements. Therefore, establish communications with the major account representative, or service design professional of the supplying utility so that their requirements can be incorporated in the facility's plans, equipment specifications, and commissioning documents. This is a two-way path of communications. The utility needs information about the proposed loads to be connected (refer to 5.4). The facility's electrical designers need information about the utility's electrical distribution system characteristics (refer to 5.5). The designer should obtain from the utility company a range of possible available fault current at the point where the utility connects. Obtaining only the maximum theoretical value is not adequate for the eventual analysis of arc flash on the user's distribution system. It is important to also know what is the possible minimum fault current available, as well as the maximum worst case available fault current.

4.3 Service availability

4.3.1 Service voltage

The service voltage selected and its characteristics for primary or secondary service are based on the utility's distribution standards and the voltage grids in the specific area of the facility. The utility should be contacted to determine the available voltages based on the load to be served and, in some cases, the geographic location of the load. The designer may become aware of service voltages provided to customers in the service area that are no longer available. Such services continue to be offered only to existing facilities and are not typically offered to new facilities.

Service is usually available at the utilization voltages, such as 240 V delta (3-phase/3-wire), 120/240 V high-leg delta (3-phase/4-wire), 208Y/120 V, 480Y/277 V, or 600Y/347 V. Utilities may have kilowatt demand limitations for each specific voltage. When the facility's load becomes too large to be supplied at the utilization voltage, due to excessive cost or excessive voltage drop, the facility should be supplied at a distribution voltage, typically, but not limited to, 4.16 kV, 12.47 kV, 13.2 kV, 13.8 kV, 26 kV, or 34.5 kV. In the case of large facilities, it may also be economically feasible to connect to the utility transmission line system. A primary substation is used to step the voltage down from transmission line levels to medium-voltage levels. Refer to 8.6 and Clause 11.

If the customer owns the medium-voltage distribution system, then the associated equipment, including transformers, should be purchased and installed by the customer. The exception would be if the utility provides all or part of the medium-voltage distribution system, in return for the right to sell power directly to tenants, or when the utility and the authority having jurisdiction (AHJ) permit more than one service in the building. In the latter case, the utility may consider each service as a separate customer, and usually the bills will be higher than a single bill.

4.3.2 Service type

The designer should discuss the type of services available in the service area supplying the facility with the utility service design professional. Services may be underground, open wire aerial, or lashed aerial cable. In addition, the utility may offer dual-service options or dedicated lines for special customer load requirements.

4.3.3 Reliability considerations

4.3.3.1 Introduction

Consistency in maintaining needed reliability throughout the entire electric system is essential. A careful evaluation of each part of the design, for reliability and maintainability, as well as that of the utility feeders and their sources is needed. For instance, the incoming feeders might have taps for other customers; be exposed to hazards; or have a history of power quality problems, including substation or line circuit breaker and recloser operations that indicate a need to be reinforced, or supplemented with an alternate set. When planning for

redundant incoming feeders, this evaluation may uncover that the two feeders are sourced from the same utility transformer or substation bus, whose failure would compromise that reliability. Resolving such issues may have large impact on project cost and/or schedule, or in worst case the resolution may not be feasible.

4.3.3.2 Facility reliability design options

The design professional should consider all possibilities of planned and inadvertent outages to determine the justification for reinforcements, such as alternate feeders or feeders from separate substations. Plan, specify, and design into the distribution system the ability to connect mobile standby generators to the incoming service switchboard in the event of a total loss of utility service. Designing in the ability to connect portable generation can be omitted when:

- Permanent standby generators are required by code or otherwise incorporated into the design
- The time to obtain a mobile generator is too long for operational conditions

Onsite generation using renewable sources (photovoltaic, wind, etc.) may enhance the reliability of the power system somewhat; they are limited by the availability of the source from which they derive the energy. Renewable sources are often intermittent; in addition, the design of the inverters of such sources may not allow for islanded operation. When this is the case, the renewable source needs to be complemented by some other type of onsite generation or stored energy source.

4.3.3.3 Utility system design

The reliability of utility service depends on generating facilities, the exposure of the transmission system from the generating plant, and more importantly on the design of the utility's distribution system. The reliability of the electric service also depends on the other loads on the same distribution system. For instance, a facility supplied at the same voltage level and on the same lines as a rock-crushing operation may incur power quality and reliability issues compared to a facility supplied from lines supplying a shopping mall or office building. Utility tariffs usually have requirements to limit the impact of customers with special loads on other customers. Distributed generation connected to the distribution system may increase reliability through the voltage support it provides. However, these sources cannot be counted upon to support adjacent loads in the event of a complete utility outage.

4.3.3.4 Utility reliability measurement criteria

Utility reliability is usually measured and reported to public utility commissions as SAIFI (System Average Interruption Frequency Index—number of interruptions exceeding five minutes in duration per year) and CAIDI (Customer Average Interruption Duration Index—average system wide interruption duration in minutes). Some utilities also measure MAIFI (Momentary Average Interruption Frequency Index). These indices are usually for the utility's entire system. The facility designer should request these indices for the specific distribution circuit that will supply the facility, or request a list of momentary and sustained interruptions on the circuit over a three- to five-year period. This will provide a more realistic expectation to design the facility's electrical system to provide the reliability needed for specific load areas such as computer data servers, cash registers, and controls for critical loads. Such measures may include, but are not limited to, uninterruptible power supplies, or standby generation.

4.3.4 Operating staff

One of the most important, and often neglected, considerations is the ability of facility staff to operate and maintain the proposed systems. Commercial buildings often have a very limited number of staff. This can be the case for industrial plants as well. This staff might be unqualified to properly and safely maintain medium-voltage systems, protective-relaying systems, or complex switching arrangements. However, a limited staff may be augmented by contracting with third-party service providers or electrical contractors if local resources can provide qualified personnel on a timely basis.

4.3.5 Electric service protection

In addition to the overcurrent and disconnecting means requirements of the National Electrical Code (NEC), articles 230 and 240, Canadian Electric Code (CEC), [section 6](#) and section 14, or local codes, facility services should be protected against electrical anomalies that may result from impacts to the electric utility's distribution or transmission system. These may include but are not limited to:

- Motor control and protection: Utility tariffs usually state that they assume no responsibility for failures, equipment, or operations due to use of the electrical energy. The utility requirements specify that customers are responsible for equipping motor controllers with protection.
- Undervoltage protection: Tripping devices to prevent sustained under-voltage operation. The under-voltage protection should be of a time-delay type to avoid unnecessary tripping during momentary disturbances or service interruptions.
- Phase protection: Tripping devices to switch off motor controllers as protection from single phasing, improper rotation due to phasing, and overheating due to current unbalance.
- Protection required for interconnecting onsite power sources to the utility system: Setting source protective devices to provide voltage and frequency support as long as possible, but tripping off devices to prevent continuing to power the utility system after utility power has been removed from the line to which the industrial or commercial facility is connected.
- Protection required for interconnecting to the utility transmission line system: High-speed fault detection and clearing is imperative to prevent a fault on the customer's system from degrading the transmission line system and reducing the levels of safety and reliability that the network provides to other customers.
- Arc flash and or other protection that enhances maintenance and operational safety: Protection to mitigate electrical hazards may be more than that required to meet the minimum requirement of installation codes, how it should be considered within the context of safety-by-design principles, and the hierarchy of hazard-control measures provided in NFPA 70E, CSA Z462, and ANSI Z10.

4.3.6 Economic considerations

4.3.6.1 Utility cost to provide service

The designer should investigate any utility interconnection costs associated with the service to the facility. Most utilities have a *line extension policy* to provide revenue credits toward utility construction costs to provide a service. If the load is not sufficient to cover costs, a customer contribution to construction may be levied on the project. Other utility costs may be levied for special or nonstandard service requests, such as dual services or dual services from separate substations, or non-standard voltages.

4.3.6.2 Other utility economic considerations

Discuss and negotiate with the utility account representative the rules and tariffs on such items as:

- a) Consideration of a more beneficial rate structure
- b) An alternative incoming voltage
- c) Location of the property line boxes or incoming service
- d) An alternative transformer winding connection, such as requesting a primary delta to grounded-wye secondary transformer instead of a transformer with a grounded-wye primary to grounded-wye secondary
- e) Use of a feeder with a history of increased reliability

The utility account representative may request:

- a) Limiting motor-starting currents, voltage dips, and flicker
- b) Providing more convenient access to routes for service or specific locations where utility metering or communication components need to be installed
- c) Installing switchgear with special features or higher ratings
 - 1) Specific manufacturer and models of equipment or components
 - 2) Protection, control, and communication requirements, for example, transfer trip via power line carrier, fiber-optic media, or microwave
- d) Installing harmonic control equipment
- e) Installing power-factor improvement equipment

4.3.7 Point of delivery

The utility should provide, in writing, the service point for the facility. This is the demarcation between utility-owned facilities and customer-owned facilities, and usually determines which party is responsible for maintenance or repair. The actual point of delivery may be the last utility pole location, utility transformer secondary terminals, or the terminals of a disconnect switch. The design engineer should consider minute details associated with the actual point of delivery, such as the scope of supply for termination hardware and field work. The requirement for manholes, handholes, or end boxes will also be included. The design should also consider whether a splice at the point of demarcation is required. If a splice is not required, details should be listed as to which party will extend conductors to meet the other, and which party is responsible for the splice or terminations for medium-voltage services.

4.4 Facility load information

Prior to discussing power costs and availability with the utility, load data for initial and future requirements should be estimated as accurately as possible. (Refer to ANSI C84.1 [B4], Chapter 3 of IEEE Std 141 [*IEEE Red Book*TM] [B24], and Chapter 3 of IEEE Std 241 [*IEEE Gray Book*TM] [B26]). If the utility has to install additional facilities to achieve the service quality needed, then a charge for these additional facilities may have to be paid by the owner. The annual operating cost can be ascertained from the utility tariff. If facility expansion is likely, check the ability of the utility to supply the increased load. The utility may need the following information:

- a) Plot plan of the area, which shows the buildings (both present and future), roadways, and other structures. Underground and overhead utility lines should be documented. Identify area allocated for utility substation when applicable.
- b) Preferred point of delivery for electric service.
- c) Estimated connected load, maximum demand and power factor, and any requirements for future increases including life-cycle load growth margins.
- d) Preferred voltage.
- e) Harmonic producing equipment, including variable frequency drives, large motors, electric boilers, welders, and X-ray apparatus, which may disturb the supply system.
- f) Any requirements for alternate, emergency, or standby service.
- g) A single-line diagram of service equipment. For medium-voltage service, show the distribution system including the sizes and ratings of fused load-interrupter switches, metal-clad or metal-enclosed circuit breakers, surge arrestors, and relaying, including current transformers and potential transformers.

Transformer descriptions should include the basic impulse insulation level (BIL), voltage taps and tap changing method (de-energized or on-load type), transformer winding connections, system grounding, and phase rotation.

- h) A load tabulation for the peak summer and winter seasons that indicates the contribution of each of the following loads to the peak demand:
 - 1) Central systems/utilities: water chilling, water heating, ventilation, air handling, humidification, space heating
 - 2) Data processing: computers and peripherals, air conditioning
 - 3) Telecommunication information centers, servers, and air conditioning
 - 4) Food service
 - 5) Lighting
 - 6) Refrigeration
 - 7) Room air conditioning
 - 8) Water heating
 - 9) Welders and compressors (e.g., maintenance shop)
 - 10) Receptacles
 - 11) Heating
 - 12) Transportation: elevators, escalators, people movers, conveyors
 - 13) Miscellaneous power: radio and television broadcasting, etc.
 - 14) Process or manufacturing loads
 - 15) Residential loads (i.e., for mixed-used commercial buildings)
- i) Rating of standby and emergency generator(s).
- j) The electrical load information should be separated by voltages and whether single-phase or three-phase. The largest motor in each category should be shown by rating (kilowatt or horsepower), together with its locked-rotor and full-load amperes. Advise when reduced voltage starting is planned for limiting motor-starting currents.
- k) Considerations for parallel operation of generation: Utility requirements for protective relaying and transformer connections should be considered if generation (i.e., synchronous, induction, or inverter connected) is to be paralleled with the utility service.
- l) Considerations for automatic bus transfer schemes (refer to 11.6.4.8).
- m) Load factor, i.e., daily and monthly.
- n) Schedule data:
 - 1) The date service and preliminary construction schedule will be required
 - 2) The dates when full estimated initial load and full load will be required
 - 3) Temporary construction service requirements

4.5 Information from the utility

When requested, the utility may provide the following information:

- a) Tariffs.

- b) Voltages available.
- c) Power factor requirements.
- d) Range of the nominal voltage and the voltage unbalance and any power quality–related parameters (refer to ANSI C84.1 [B4]).
- e) For medium voltages, insulation-coordination data:
 - 1) Basic impulse insulation level (BIL) of equipment
 - 2) Ratings of surge arresters:
 - i) Front-of-wave test data
 - ii) Lightning protective level (impulse protective level)
 - iii) Switching protective level
 - 3) Lightning protection methods employed (e.g., “skywires”), if any
- f) Point of delivery of electric service, when preferred point is not acceptable.
- g) Line route from the property line to the point of delivery for any portion of the line installed by the utility.
- h) Any charges for service, including cost of any underground portion of the line.
- i) The utility may provide options for the underground service: direct burial cable, or conduit and manhole system.
- j) Electric service requirements, including:
 - 1) Metering
 - 2) Service equipment specifications
 - i) Protective relay specifications
 - ii) Station battery specifications
 - 3) Transformer vault and network specifications
 - 4) Service transformer specifications
 - 5) Specifications for transfer switches and other types of transfer schemes
 - 6) Fire pump connection specifications
 - 7) Fire alarm and exit lighting connection specifications
 - 8) Emergency operations facility connection specifications
 - 9) Operation and maintenance of service equipment specifications
 - 10) Protection of motors specifications
 - 11) Motor-starting inrush current specifications
 - 12) Power quality specifications including voltage flicker, telephone interference factor (TIF), and total harmonic distortion limitations
 - 13) Communication and power system data interface requirements
 - 14) Harmonic limitation requirements for variable frequency drives
 - 15) Power factor improvement capacitor/harmonic filter connection requirements
 - 16) Phase load balance requirements

- 17) Electrical identification of wiring
 - 18) Phase rotation at each voltage level
 - 19) Single-phase equipment (for example, welders, etc.) inrush current limitations
 - 20) Surge protection and equipment basic impulse insulation level requirements
 - 21) Tree trimming and vegetation control specifications around service equipment
 - 22) Distributed power generation connection and protection requirements
 - 23) Automatic transfer scheme requirements between two utility feeders or between utility feeder(s) and owner's generator(s)
 - 24) Requirements for customer-owned substations
- k) Available minimum and maximum short-circuit capacity of the supply system, accounting for likely future changes to the utility distribution system (maximum values are used for determining suitability of interrupters applied in the system while arc flash incident energy calculations should use these and minimum values to determine maximum arc flash energy conditions). Information for single-line-to-ground faults should also be obtained for medium-voltage services.
 - l) Protective device time current coordination information.
 - m) Any special local exception to the NEC, which applies to utility-associated equipment.
 - n) Recommended ratios and taps for transformers provided by the customer.
 - o) Availability and cost of an alternate or standby electric supply.
 - p) Historical as to the reliability of substation transmission and distribution feeders (SAIFI yearly and CAIDI, refer to IEEE Std 493™ [B32]).

Prior to requesting short-circuit data, the user must consider the purposes for the data. The major uses of utility supply short-circuit data are for determining the following:

- *Withstand and interrupting ratings of equipment.* The maximum available fault current values are required.
- *Settings of protective devices.* The range of probable fault values is required, although sometimes only the maximum fault currents are considered by some users.
- *Prospective arc flash incident energy.* The range of probable fault values is necessary, as emphasized in IEEE Std 1584™.
- *User system design.* This includes motor starting criteria, transformer taps, and other load issues. This assessment must consider the range of relevant utility data. For example, if two utility lines are available, any one of which will support the load, but both of which are required to start a large motor, this range of data becomes important. If, however, the same motor must be started with only one utility line available, a different range of utility data is required.

For industrial and commercial projects, it is normal to attempt to determine the “maximum and minimum fault currents,” and use that information to determine arc flash incident energies. Sometimes the minimum fault current is also used for other aspects of the design of overcurrent protection, but often the designers of these systems forget about this consideration. When the “minimum fault current” is requested, the utility engineer providing the information may consider scenarios that are not applicable to the power system being designed.

The electrical supply utility engineer starts with the present system configuration. He routinely determines the fault currents (three-phase, single-line-to-ground, and occasionally line-to-line and double-line-to ground) for this configuration. He often will have an anticipated future configuration, perhaps a 10-year “look-ahead”

model, and will determine the probable fault currents for that condition. However, when asked for a “minimum fault,” the methodology varies widely. Sometimes the “minimum fault” provided is actually a single-line-to-ground fault. Usually the utility engineer considers N-1, N-2, etc., cases. N-1 means any one element is taken out of service. In practice, there will need to be a large number of N-1 cases run, each taking a different element out of service, to determine the range of available fault currents for *N-1*. Similarly, *N-2* means two different elements are simultaneously taken out of service. In some cases, the configuration which corresponds to “minimum fault” cannot support the user’s load currents. These are very important calculations for the utility, because they are used in assessing protective relay settings. However, they may not be applicable to the user’s system because it is not a practical operational condition.

Another consideration is the fault contribution from large motors connected to the systems of adjacent users. If the user is located in an industrial complex where adjoining users connected to the same power supply network have large motors in operation, the fault contribution from these motors will often be ignored. This may not be significant if the motors in question are separated from the user’s fault location of interest by two or more power transformers. However, it could have an impact on some supply infrastructure (such as circuit breakers), which may be within the scope of the user or the supply authority, depending on details of the proposed utility connection.

In order to obtain appropriate fault current values from the supply utility, the user needs to discuss present and probable future network configurations which will support the user’s loads. Some of these configurations may not permit a large motor to start, but configurations which can realistically maintain the user’s running load need to be considered. Situations where load curtailment is required should be addressed separately, if relevant. (Load curtailment is not feasible for some facilities, and very practical for others.)

From this set of agreed network configurations, the maximum and minimum three-phase and single-line-to-ground fault currents and impedances need to be determined at the agreed point of connection between the supply authority and the user. The range of normal operating voltages at this point of connection should also be requested.

Any potential fault contributions from other connected user’s motors need to be discussed. If this is a likely condition, but not included in the supply utility’s data, some assessment of the order of magnitude of these possible contributions needs to be determined, whether by the supply utility, the user, or a third party.

4.6 Interrelated utility and project factors that influence design

Other factors that may influence the facility’s interconnection with a utility service are:

- a) Type, size, shape, and occupancy purposes of the building or buildings
- b) Voltages and voltage ranges that are available at the site [refer to Chapter 3 of IEEE Std 141 (*IEEE Red Book*TM) [B24] and Chapter 3 of IEEE Std 241 (*IEEE Gray Book*TM) [B26]]
- c) Electrical rate plans available
- d) Availability of aerial or underground service and of network sources
- e) Type and rating of building utilization equipment
- f) Economics of utilization voltage distribution
- g) Necessity of changing the service voltage, e.g., from 480Y/277 V to a medium service voltage i.e., 4160Y/2400 V or 12 470 V, 13 200 V, or 13 800 V
- h) Complete or partial replacement of equipment in a modernization project
- i) Application of energy-conserving projects

- j) Intent to use fuel cells, microturbines, photovoltaics, or other onsite sources of electric energy that can be connected to the utility system
- k) Reliability and maintainability of supply
- l) Utility outages and shutdown planning
- m) Future planning: Learn the utility's plans for maintaining the local distribution system or possibly replacing or upgrading it in the future
- n) Economics of the distribution system as a consequence of available fault levels of utility services and customer-furnished fault current limiters, such as transformers, reactors, system neutral grounding, and current-limiting protective devices
- o) Coordination with other utilities such as natural gas, sewage, and water

5. Electric rates

5.1 Demand and fixed charges

Demand charges cover all generally predictable utility costs, such as depreciation, interest, and insurance. Capital investments for land, buildings, generating equipment and switchgear, transmission lines, and structure transformation and distribution equipment are depreciated over the estimated or specified life of the equipment. Demand charges reflect the investment required by the electric utility to serve the customer's maximum rate of consumption (demand). The demand is determined by a demand meter. In most cases this is a standard kilowatt-hour meter with demand interval registers that record the kilowatt-hour consumption over the demand interval period. In electro-mechanical meters, the demand is determined by multiplying the kilowatt-hour registration times the number of demand intervals in one hour. For a 30-min demand interval, this would be the kilowatt-hour registered in an interval multiplied by 2. Digital meters can calculate this using software algorithms and have capabilities for multiple types of interval periods (i.e., fixed or sliding. Refer to 7.6).

5.2 Energy and variable charges

Utility rates include cost items such as fuel, operating labor, maintenance, raw materials, etc. There may also be a *fuel adjustment clause* to compensate the utility for the market price of fuel above its long-term contract base rate. Some states in the United States, and some provinces in Canada, have de-regulated their electric utilities, resulting in competition to supply energy. These utility tariffs provide separate costs for variable distribution charges, transmission system charges and energy charges. Customers in these service territories may shop the market for third-party energy suppliers. The serving utility provides "wire" or "delivery" service charges, which may still be based on kilowatt demand and kilowatt-hour energy delivered. Most de-regulated utilities remain a "last resort" supplier of energy, if the customer does not select a third party energy supplier. The resulting energy rates are published in their tariffs. Customers in these de-regulated markets should research an alternate supplier. They should provide expected kilowatt demand, expected kilowatt-hour consumption, an estimated load factor, and inquire about the impact of power factor. To arrive at the most economical tariff, the design professional should evaluate the following tariff conditions:

- a) Characteristics of service:
 - 1) Voltages and types of systems available
 - 2) Maximum demand in kilowatts or kilovolt-amperes
 - 3) Demand interval: 15 min, 30 min, or 60 min
 - 4) Energy consumption in kilowatt hours
 - 5) Power factor: minimum required and recommended

- 6) Voltage unbalance
- 7) Power quality: total harmonic distortion, allowable voltage dips and flicker due to motor starting
- b) Installation and maintenance of overhead and underground facilities
- c) Space for transforming and other utility apparatus
- d) Interior distribution arrangement
- e) Service equipment
- f) Customers wiring and equipment
- g) Metering: special meters, submeters, tenant meters
- h) Billing: minimum bills, terms and conditions
- i) Load adjustments by the Independent System Operator at times of emergency
- j) Conjunctural billing
- k) Off-peak rates, seasonal rates, time-of-day rates
- l) Incentive rates
- m) Real-time pricing
- n) Emergency service, auxiliary service, standby service, backup service
- o) Interruptible service
- p) Purchases of installed generating capacity
- q) Charges due to excess load above “standard load density” for building type
- r) Charges or credits associated with power factor or other power quality requirements
- s) Fuel cost adjustment clause; taxes; nuclear plant decommissioning fee
- t) Charges for multiple supplies from different substations for reliability
- u) Charges for utility-installed and operated uninterruptible power supply systems
- v) Availability and costs for electrical distribution equipment maintenance and repair services
- w) Guaranteed outage duration
- x) Credit for inability to deliver service
- y) Compensation for failing to meet in-service date
- z) Compensation for metering system failure

5.3 Power factor credits and penalties

The power factor of the load may be required to be 85% or 90% with a credit for a higher power factor and a penalty for a lower power factor.

6. Electric utility metering and billing

6.1 Introduction

An understanding of utility metering and billing practices is important for evaluating service arrangements. The design, usage, and load characteristics for a given application should be carefully weighed before selecting service voltage and metering characteristics. When momentary high demand loads, high seasonal loads, or

low power factor loads are present, billing penalties may also be incurred. High load factor or high power factor loads may merit a billing allowance or credit.

6.2 Metering by type of premises

6.2.1 Introduction

The availability of a specific metering and billing arrangement depends on the characteristics of the business premises, type of load involved, and utility tariffs.

6.2.2 Single-occupancy building

A single-occupancy building will be metered by the utility with a watt-hour-demand meter. With multiple services, watt-hour-demand meter readings may be added together to take advantage of lower rates, and the demands on two or more services may be totalized to benefit from the diversity of their demand.

6.2.3 Multiple-occupancy building

Multiple-occupancy buildings are typically equipped with an individual meter for each customer (owner and tenants), except in cases where light and power are included in the tenant's rent, in which case a master metering may be utilized. In some localities, buildings may be submetered so the utility's customer buys wholesale power on a utility master meter, and then resells it to the tenants at legally prescribed rates using private meters.

6.2.4 Directly-metered multiple-occupancy building

Where the tenants are directly metered, by the utility or by submeters, provide sufficient flexibility in the metering arrangement to facilitate changes, for example, a change of tenant.

6.3 Metering by service voltage characteristics

Metering of incoming electric service may be located on the high-voltage or low-voltage side of the transformer, depending on the tariff. When the metering is on the high-voltage side of the transformer, the transformer losses will be metered and charged to the customer. Where the service point is on the high-voltage side, but the meter is on the low-voltage side, then the utility may add a fixed percentage to the bill, such as 2%, to cover the transformer losses. In some cases, the customer is given a discount to offset this loss.

6.4 Meter location

Since all meter locations are subject to utility approval, review the meter locations with the utility at the preliminary design stage. Utilities require accessibility for meter reading and maintenance purposes, and suitable meter protection. Where remote meter reading is performed, the utility may require a dedicated telephone line. Where the customer has distributed generation or a contract to generate electricity upon order of the utility during emergencies, then an additional, separate meter may be required to be installed at the generating set together with remote reading capability and a requirement for a dedicated telephone line. Utility requirements for meter heights above the standing surface may differ depending on whether the location is indoors or outdoors.

Meters installed indoors may be applied in:

- Secondary distribution points
- A suitable meter room