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**IEEE Recommended Practice for
Emergency and Standby Power
Systems for Industrial
and Commercial Applications**

An American National Standard

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Emergency and Standby
Power Systems for
Industrial and Commercial Applications**



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Emergency and Standby
Power Systems for
Industrial and Commercial Applications**

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of the
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Foreword

(This Foreword is not a part of ANSI/IEEE Std 446-1987, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications.)

In 1968 the Industrial and Commercial Power Systems Committee within the Industry and General Applications Group of the Institute of Electrical and Electronics Engineers recognized that a need existed for a publication that would provide guidance to industrial users and suppliers of emergency and standby power systems.

The nature of electric power failures, interruptions, and their duration covers a range in time from microseconds to days. Voltage excursions occur within a range from 20 times normal (or more) to a complete absence of voltage. Frequency excursions can vary as widely in many forms, from harmonics to direct current. These variables occur due to a multitude of conditions both in the power system ahead of the point of the user's service entrance and following the service entrance within the user's area of distribution.

Such elements as lightning, automobiles striking power poles, ice storms, tornadoes, switching to alternate lines, and equipment failure are but a few of the causes of interruptions in the electric power supply ahead of the service entrance.

Within the user's area of distribution are such elements as short and open circuits, undersized feeders, equipment failures, operator errors, temporary overloads, single-phasing unbalanced feeders, fire, switching, and many other generators of power interruption or failure.

In the past the demand for reliable electric power was less critical. If power was completely interrupted too often, another source was found. If voltage varied enough to cause a problem, a regulator or a larger conductor was installed. As processes, controls, and instrumentation became more sophisticated and interlocked, the demand developed to shorten the length of outages. Increased safety standards for people required emergency and exit lighting. Many factories added medical facilities that needed reliable electric power.

With the advent of solid-state electronics and computers, the need for continuous, reliable, high-quality electric power became critical. Many installations required uninterruptible power, virtually free of frequency excursions and voltage dips, surges, and transients.

In 1969 a working group was established under the Industrial Plants Power Systems Subcommittee of the Industrial and Commercial Power Systems Committee to collect data and produce a publication entitled "Emergency Power Systems for Industrial Plants." Later that year the scope of the work was enlarged to include standby power since in meeting various needs the two systems were often found to be intertwined, or one system served multiple purposes.

As the work progressed it became apparent that industrial and commercial needs contained more similarities than differences. Systems available to supply the required power to industry were found applicable to both fields. Once again the scope of the work was expanded to include commercial requirements. The working group was changed to the status of a subcommittee under the Industrial and Commercial Power Systems Committee, and the proposed publication was directed toward establishing recommended practices. As a result of additional organizational changes, the Emergency and Standby Power Systems Subcommittee is now under the Power Systems Engineering Committee of the Industrial and Commercial Power Systems Department.

This second revision of the IEEE Orange Book includes new and updated material. The sections on maintenance, protection, grounding, and industry applications have been revised and expanded to cover a new and broader scope. In addition, the previous chapter on systems and hardware has been divided into two new chapters providing a more logical separation and presentation of equipment.

This IEEE Recommended Practice continues to serve as a companion publication to the following other Recommended Practices prepared by the IEEE Industrial and Commercial Power Systems Committee:

Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book), ANSI/IEEE Std 141-1986.

Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book), ANSI/IEEE Std 142-1982.

Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book), ANSI/IEEE Std 241-1983.

Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book), ANSI/IEEE Std 242-1986.

Recommended Practice for Industrial and Commercial Power System Analysis (IEEE Brown Book), ANSI/IEEE Std 399-1980.

Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book), ANSI/IEEE Std 493-1980.

Recommended Practice for Electric Systems in Health Care Facilities (IEEE White Book), ANSI/IEEE Std 602-1986.

Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities (IEEE Bronze Book), ANSI/IEEE Std 739-1984.

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Chapter 1

Scope

This standard presents recommended engineering principles, practices, and guidelines for the selection and application of emergency and standby power systems. Industrial and commercial users' needs are outlined and discussed and the material is primarily presented from a user's viewpoint. However, handling of the effects of power system disturbances obviously requires close cooperation between users, electric utilities, and equipment manufacturers, and the part played by each in the solutions to users' needs is vital to the proper selection and application of equipment.

Those responsible for reliable power for industrial and commercial operations are provided with itemized operational needs that form the basis for emergency and standby power system design and application. Industrial and commercial needs are sufficiently described, with a distinction made between the two with reference to mandatory laws, regulations, codes, and standards.

Chapters such as "General Need Guidelines" provide electric utility companies and equipment manufacturers with information on user requirements that allow for closer coordination in meeting specific power supply needs and proper equipment and system design for an efficient, practical, and reliable installation. Equipment manufacturers have provided technical and economic information on available hardware and systems, allowing recommendations for the requirements of various types of installations.

Technical guidelines in specialized areas of design such as protection and grounding, as specifically required in emergency and standby power systems, are presented in separate chapters. These chapters assist the designer in the actual application of equipment. Additional information on applications by specific industry types is also included in a separate chapter. This provides users and suppliers of emergency and standby power systems with vital information on how various industries meet their specific users' needs.

To round out the proper selection and application of emergency and standby power systems, proper maintenance guidelines must be included. Guidelines for specific types of equipment are discussed, recognizing that experience and economic factors play a large part in how various users must maintain equipment.

In this standard, the reader will find answers to the following questions about guidelines.

- (1) Is an emergency or standby power system, or both, needed, and what will it accomplish?
- (2) What types of systems are available and which can best meet the users' needs?
- (3) What are the maintenance and operating requirements for maintaining system reliability?
- (4) Where can additional information be obtained?
- (5) How should the most suitable system be designed and applied to the existing power system?

The following industries and fields are considered specialized and beyond the scope of inclusion and direct address by this standard: transport, government, military, and utility.

Chapter 2

Definitions

2.1 Introduction. This chapter is intended to conveniently provide terms and definitions applicable to this standard for the purpose of aiding in its overall understanding. These terms and definitions are in no way intended to supersede, contradict, or change those provided in ANSI/IEEE Std 100-1984 [1].¹

automatic controller (process control). A device that operates automatically to regulate a controlled variable in response to a command and a feedback signal.

automatic transfer switch. Self-acting equipment for transferring one or more load conductor connections from one power source to another.

availability. The fraction of time within which a system is actually capable of performing its mission.

bypass/isolation switch. A manually operated device used in conjunction with an automatic transfer switch to provide a means of directly connecting load conductors to a power source and of disconnecting the automatic transfer switch.

commercial power. Power furnished by an electric power utility company; when available, it is usually the prime power source. However, when economically feasible, it sometimes serves as an alternative or standby source.

computer. (1) A machine for carrying out calculations. (2) By extension, a machine for carrying out specified transformations on information.

current withstand rating. The maximum allowable current, either instantaneous or for a specified period of time, that a device can withstand without damage.

data processing. Pertaining to any operation or combination of operations on data.

data processor. Any device capable of being used to perform operations on data, for example, a desk calculator, tape recorder, analog computer, or digital computer.

¹ The numbers in brackets correspond to those of the references listed at the end of this chapter; when preceded by B, they correspond to the bibliography at the end of this chapter.

dropout voltage (or current). The voltage (or current) at which a magnetically operated device will release to its de-energized position. It is a level of voltage (or current) that is insufficient to maintain the device in an energized state.

emergency power system. An independent reserve source of electric energy that, upon failure or outage of the normal source, automatically provides reliable electric power within a specified time to critical devices and equipment whose failure to operate satisfactorily would jeopardize the health and safety of personnel or result in damage to property.

firm power. Power intended to be always available, even under emergency conditions.

forced outage. A power outage that results from the failure of a system component, requiring that it be taken out of service immediately, either automatically or by manual switching operations, or an outage caused by improper operation of equipment or human error. This type of power outage is not directly controllable and is usually unexpected.

frequency droop. The absolute change in frequency between steady-state no load and steady-state full load.

frequency regulation. The percentage change in emergency or standby power frequency from steady-state no load to steady-state full load:

$$\%R = \frac{F_{n1} - F_{f1}}{F_{n1}} \cdot 100$$

harmonic content. A measure of the presence of harmonics in a voltage or current waveform expressed as a percentage of the amplitude of the fundamental frequency at each harmonic frequency. The total harmonic content is expressed as the square root of the sum of the squares of each of the harmonic amplitudes (expressed as a percentage of the fundamental).

load shedding. The process of deliberately removing preselected loads from a power system in response to an abnormal condition in order to maintain the integrity of the system.

off-line operation. (1) Pertaining to computer systems not under direct control of the central processing unit. (2) Pertaining to uninterruptible power supply systems whereby an inverter is off during normal operating conditions.

on-line operation. (1) Pertaining to equipment or devices under direct control of the central processing unit. (2) Pertaining to uninterruptible power supply systems whereby an inverter is on during normal operation conditions.

power failure. Any variation in electric power supply that causes unacceptable performance of the user's equipment.

power outage. Complete absence of power at the point of use.

prime mover. The machine used to develop mechanical horsepower to drive an emergency or standby generator to produce electrical power.

prime power. That source of supply of electrical energy that is normally available and used continuously day and night, usually supplied by an electric utility company, but sometimes supplied by base-loaded user-owned generation.

real time (processing). Pertaining to the actual time during which a physical process transpires or pertaining to the performance of a computation during the actual time of related physical processing in order that results of the computation can be used in guiding the physical process.

redundancy. Duplication of elements in a system or installation for the purpose of enhancing the reliability or continuity of operation of the system or installation.

scheduled outage. A power outage that results when a component is deliberately taken out of service at a selected time, usually for purposes of construction, preventive maintenance, or repair. This type of outage is directly controllable and usually predictable.

separate excitation. A source of generator field excitation power derived from a source independent of the generator output power.

shunt excitation. A source of generator field excitation power taken from the generator output, normally through power potential transformers connected directly or indirectly to the generator output terminals.

standby power system. An independent reserve source of electric energy that, upon failure or outage of the normal source, provides electric power of acceptable quality so that the user's facilities may continue in satisfactory operation.

transient. That part of the change in a variable, such as voltage or amperage, that disappears during transition from one steady-state operating condition to another.

uninterruptible power supply (UPS). A system designed to automatically provide power, without delay or transients, during any period when the normal power supply is incapable of performing acceptably.

utility power. Synonym: **commercial power.**

2.2 References. The following publication shall be used in conjunction with this chapter.

[1] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.²

² ANSI/IEEE publications can be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from Publication Sales, the Institute of Electrical and Electronics Engineers, Service Center, Piscataway, NJ 08854.

Chapter 3

General Need Guidelines

3.1 Introduction. While everyone who uses electric power desires perfect frequency, voltage stability, and reliability at all times, this cannot be realized in practice. Within a complex facility, the requirements are continually changing and becoming more demanding and interlocked.

The supplying utility cannot be expected to provide a perfect power supply because many of the causes of power supply disturbances are beyond the control of the utility. For example, automobiles hit poles, animals climb across insulators, lightning strikes overhead lines, and cyclones, hurricanes, and high winds blow tree branches and other debris into lines.

Lightning, wind, and rain produced by thunderstorms cause power failures in the form of power interruptions and transients. Figure 1 is useful in determining the probability of such power failures depending upon the user's geographic location. However, most utilities or commercial power companies, through the use of proper shielding and surge arrestors, can provide service that is of equal reliability in any area.

Figure 2 shows the density of tornadoes in several states. These violent local storms take their toll on power systems, as do more widely located storms, such as hurricanes, ice and snow storms, and floods. The weighted consideration must be based on their frequency and severity in the user's location.

Although there is less chance for an interruption on an underground system, and although an underground system has fewer dips, the duration of any interruption that occurs may be much longer because of the longer time required to find out where a cable failure occurred and to make repairs.

Even the operation of protective devices can cause power supply disturbances. As an example, overcurrent and short-circuit protective devices require excessive current to operate and will be accompanied by a voltage dip on any line supplying the excessive current until the device opens to clear the fault. Devices opening to clear a lightning flashover with subsequent reclosing cause a momentary interruption.

Utility companies have little practical control over, and thus cannot accept the responsibility for, disturbances on their systems. This is illustrated by the text taken from a typical utility sales contract: "The power delivered hereunder shall be three-phase alternating current at a frequency of approximately 60 Hz and at a nominal

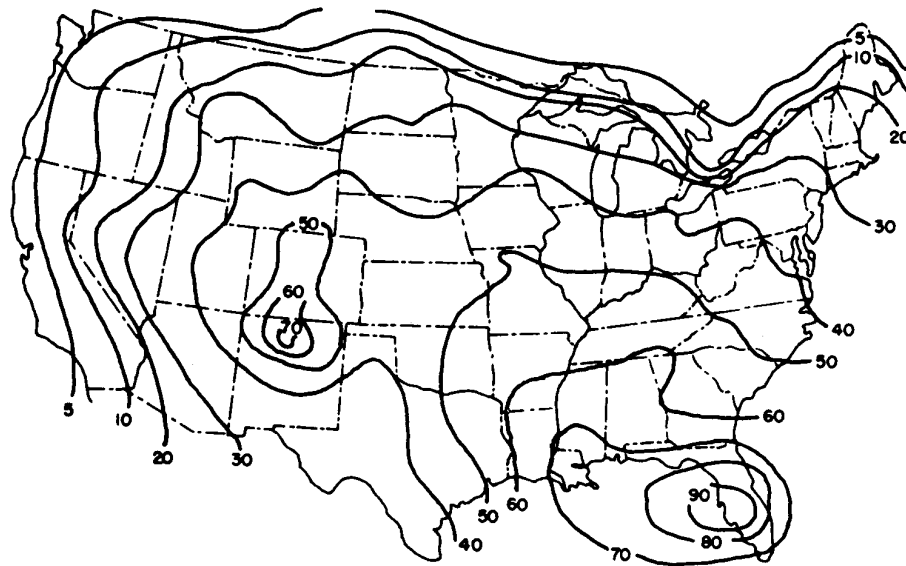


Fig 1
Average Number of Thunderstorm Days per Year

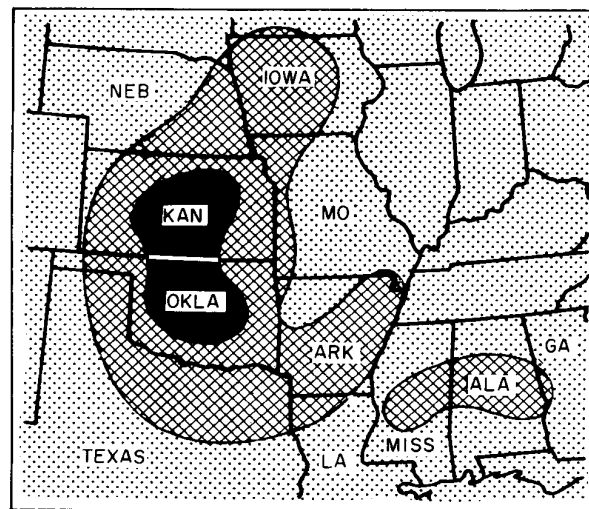


Fig 2
Approximate Density of Tornadoes
Cross-Hatched Areas — 100-200 in 40 Years
Black Area — Over 200 in 40 Years
(See [23], 3.15.1)

voltage of 208Y/120 V. Except for temporary periods of abnormal operating conditions, variations from normal voltage shall not exceed 5% up or down. The utility will use reasonable diligence to provide a regular and uninterrupted supply of power, but in case such supply should be interrupted for any cause, the utility shall not be liable for damages resulting therefrom."

It is obvious that utility companies are unwilling to make power quality or continuity guarantees, and rightly so.

In several instances, utility companies have recognized the limitations of their power quality and have offered auxiliary equipment with special purchase agreements to satisfy the needs of those who use sensitive utilization equipment.

Utility companies are by no means the only source of power system disturbances. Disturbances and outages also occur in the plant system through the loss of power due to short circuits in wiring and failures of local generation including emergency and standby equipment. *Noise* is generated in otherwise acceptable electric power by motors, welders, switches, semiconductor-controlled rectifier (SCR) gating, dielectric heating, arcing short circuits, and a myriad of other sources.

Ordinary power meters and instrumentation cannot be used to measure power transients or disturbances. Recording devices with extremely fast response must be used to detect, measure, and record disturbance magnitudes and durations. Most disturbances will not only vary within a given 24 h period, but depending on the geographical area, could be subject to seasonal variations. Usually, there are no simple methods available to record, diagnose, and classify the nature of the power problems.

Any meaningful data with regard to power quality, or lack of it, will be obvious only after conducting a thorough and detailed measurement recording and analysis program. Such a program would include the monitoring of an incoming power line over a representative period of time. Since much of the instrumentation is costly (typically \$3000-\$16 000) in relation to its limited duration usage, rental arrangements are often a popular choice.

Since ideal power quality and continuity can seldom be obtained from the supplying utility, this text has been prepared to indicate how the effects of power supply disturbances may be reduced to acceptable levels, or even eliminated. These reduction methods include

- (1) Modification of the design of utilization equipment so as to be impervious to power disturbances and discontinuities
- (2) Modification of the prime power distribution system to be compatible with utilization equipment
- (3) Modification of both systems and equipment to meet a criterion that is realistic for both
- (4) Interposing a continuous electric supply system between the prime source and the utilization equipment; this will function as a *buffer* to external sources of transients, but depending on the design, could increase the magnitude of load induced disturbances

Almost any significant deviation from normal power parameters may be capable of causing problems with some electronic equipment. Steady or slow deviations that exceed the product design range of line voltage or frequency can affect the

shaft speed of motors, the force and speed of actuators, and the conversion of alternating voltage into regulated dc voltage for electronic circuit operation. As line voltage approaches product design limits, this often reduces the ability of the product to sustain, without incident, a line voltage transient as described in the following. Of course, some electronic circuits are more susceptible than others. This depends upon specific application and design.

Most frequent among excursions from normal line conditions are those classed as voltage transients. These often contain an initial fast voltage rise or fall time (sometimes oscillatory) followed by a slower, longer duration change. Thus one transient event may contain both fast impulses or noise and a slower change in voltage.

Fast voltage impulses and noise generally have little direct effect upon the smooth, even flow of power to such devices as motors and ac to dc power conversion equipment. The flywheel effect of motors and the energy storage in filters for reducing radio frequency interference and ripple in rectified dc output current of ac to dc converters keep the fast voltage changes from affecting their outputs directly. Excessively large impulses or noise bursts and inadequate filtering may result in component voltage overstress or in the premature triggering of control circuit elements such as SCRs and TRIACs. Otherwise, very short duration impulses and high-frequency noise have little effect upon electronic circuits via power supply paths. More often these disturbances reach sensitive electronic circuits by more subtle paths through circuit grounds where power and signal ground circuit paths intersect. This dictates that care be taken in the location of connections and routing of ground conductors in addition to the more obvious precautions taken to reduce the number and amplitude of transients.

Without a good power disturbance monitor to measure and record disturbances continuously, there is a tendency to make judgments regarding disturbances in the power source in terms of their effects upon various electrical loads. When the lights go out and the electrical equipment all stops working, this is usually a fairly good indication of a power interruption. However, if the lights merely flicker or the electronic equipment malfunctions, it is difficult to judge whether or not there has been a severe change in voltage for a very short time or a very small voltage change for a much longer time. One cannot determine without a disturbance monitor whether or not the disturbance was unusually severe or the electronic equipment was unusually susceptible to the disturbance. Without the necessary features in a disturbance monitor, one cannot tell if the source of the disturbance was external to the load equipment or was the load equipment itself.

For practical reasons and convenience, power disturbances should be defined in terms that are related to practical methods of measurement. When power disturbance limits are given in the specifications for electrical and electronic equipment, use of the same terminology and definitions used in measurement will make it easier to resolve problems and in some cases will help identify the responsibility.

For purposes of later discussions, disturbances in ac power may be classified as deviations in one or more of the following areas:

- (1) Voltage
- (2) Wave shape

- (3) Frequency
- (4) Phase relationships

Of these, the most frequently encountered deviations occur in voltage as follows:

- (1) Steady-state values (slow average), including unbalance
- (2) Outages and interruptions
- (3) Surges and sags
- (4) Impulses and noise

NOTE: The term *transients* applies loosely to items (3) and (4).

The steady-state value is measured with a true rms-actuated, rms-reading voltmeter or the equivalent. The instrument should be damped, or otherwise, the readings must be averaged over a 5–10 s averaging time so that a succession of readings will indicate the gradual, long-term changes in averaged rms voltage level. This is also known as slow-average rms voltage. Most deviations in steady-state voltage are caused by voltage drops in power lines, transformers, and feeders as load is increased. When step voltage corrections are made by such means as transformer tap changing or by adding or removing capacitors, transients will be generated at the time of the step change. In addition, the change that corrected an undervoltage condition as the load increased will have to be reversed later when the load decreases. Otherwise, excessive overvoltage may result. Voltage is usually changed gradually in many small incremental steps. Occasional large step changes can occur.

The worst steady-state voltage deviations are likely to occur in areas where the total load approaches and even exceeds the capacity to generate or distribute power. In spite of short-time overload ratings, it becomes necessary to reduce load during periods of peak loading such as during heat waves when air conditioning is added to all the other normal loads. Under such conditions, not only may there be an unusually large voltage drop between power source and load, but there may also be a planned voltage reduction to relieve utility system loading. This voltage reduction is known as a *brownout*. With reductions of 3%, 5%, or even 8% at points where voltage is regular, the voltage reduction at load points may be an additional 5–10%.

The most common protection against brownouts is some form of voltage regulation, preferably one that has sufficiently low internal impedance and fast response time to avoid disturbances created by load changes and by phase controlled load regulation (where used).

When a planned brownout fails to relieve the utility power system overload enough to supply energy at reduced voltage to all users, one remaining alternative is to shed loads in a rotating sequence known as a *rolling blackout*. Under some emergency plans, certain noncritical loads would be shed for the duration of the overload. A few known critical loads would not be disturbed. The remainder would be subjected to power interruptions lasting 10–20 min each on a rotating basis among groups of subscribers, sufficient to relieve the overload by means of the rolling blackout.

Unequal loading on polyphase lines or single-phase three-wire lines is often the cause of voltage imbalance. Voltage control devices generally operate to regulate the average of the phase voltages, or sometimes just one of the phase voltages, on

the assumption that the other phases will be equal to it. The most common corrective measure is to balance the loading among the phases. However, power sources with high internal impedance are more critical in a requirement to distribute loads evenly in order to avoid excessive voltage imbalance. Selection of a delta-connected primary with a wye-connected secondary rather than a four-wire wye input and output will help distribute unequal phase loading.

Large computer installations with an uninterruptible power supply (UPS) capable of supplying the computer's power needs for 5–15 min would need supplementary standby power to operate auxiliary building services, such as air conditioning, and to replenish the storage battery energy in order that the computer system could continue to remain functional through an extended power outage. Diesel- or gas-turbine-driven generators fill this need.

Nonpermanent departures from the normal line voltages and frequency can be classified as disturbances. Disturbances include impulses, noise, transients, and even some changes in frequency or sudden phase shifts during synchronizing operations. Although the frequency and phase shift events may rarely be encountered when large loads are switched in power networks, these may frequently be encountered in small independent power sources during synchronizing and switching of loads from one source to another.

The more usual disturbance involves line voltage impulses, noise, transients, steady-state voltage change, or some combination of these. Most disturbances on a power system are of short duration. Studies indicate that 90% are less than 1 s in duration. Some 80–85% involve only one phase of a three-phase system. The following is an attempt to group disturbances in relation to their duration and possible causes.

3.1.1 1 s–1 min. Usually attributed to severe faults accompanied by 50–100% voltage loss on one or more phases, these disturbances often result in an outage on some circuit. Faults often involve all three phases and may be the result of a downed pole, a tree or crane on the line, a breaker lockout, or an in-line fuse blowing. If the critical load is on the cleared side of the fault, the disturbance becomes an outage. If it is on the power source side of the fault clearing device, the normal voltage may be restored.

3.1.2 10–40 Cycles. The disturbances are surges and sags due to operation of relatively slow-speed breakers, reclosures in clearing faults on adjacent circuits, tap changing of in-line transformers and regulators, and the starting of motors, either across the line or reduced voltage start.

3.1.3 0–8 Cycles. The disturbances are surges, but more often sags, caused by a fault and subsequent fuse action or high-speed circuit breaker operation on adjacent circuits. Switching surges and inrush current transients caused when energizing electrical devices create short-duration voltage sags and surges. Single-phase loads on a multiline power source (single- or three-phase) create voltage surges on the unloaded phases if they cause sags on the loaded phase.

3.1.4 0.001–1 Cycles. These disturbances are short-duration surges and sags caused by lightning arresters, load and capacitor switching, and short-duration faults. Any disturbances lasting less than 1 cycle may be difficult to compare directly with those lasting longer. Measurement of voltages for periods longer than

one cycle is conveniently done in terms of rms values (the root mean square of all values during the cycle). Since most utilization voltages are supplied via a transformer in series with the power source, it is unlikely that a voltage surge at its output will exceed 130–150% of nominal volt-seconds (the area under a half sine wave). Core saturation in the transformer tends to limit this. Greater input volt-seconds that would push the magnetic core into deeper saturation would result in overcurrent tripping. The net result is that the transformer can pass very high voltages if they are of short duration, but the longer they persist, the lower the voltage must be.

3.1.5 Less than 0.001 Cycle. These disturbances are generally classed as impulses. (They originate as the fast portions at the beginning or end of switching transients that may have much longer durations. They may be associated with disturbances of all kinds, the more severe of which are natural lightning, electrostatic discharge, and the switching of nearby loads sharing the same power feeder.)

Impulses may be of either polarity, single fast-rise and fast-fall time event, or they can be damped-oscillatory in form. There can be bursts of multiple impulses. They can be synchronized with the power frequency so as to occur at the peak of each voltage wave (arcing fault, for example), or they can occur at random.

Impulses are measured in most instrumentation systems as voltage peak deviation from the sine wave voltage. This is usually accomplished by use of a high-pass filter (simple capacitor-resistor combination) to block the power frequency voltage. If a positive-going impulse occurs at the positive peak of a sine wave, the maximum instantaneous voltage will be the sum of the two. If not measured or expressed in volts, impulse amplitude limits are expressed in terms of the nominal voltage peak. For example, an impulse of *3 times nominal* referred to a 120 V rms nominal voltage would imply an impulse 3 times as great as the peak value of the sine wave. This is $\sqrt{2} \cdot 120 \cdot 3 = 509$ V peak value for the impulse. If this occurred at the peak of the sine wave and was in the same direction, the two would add to give $509 + (\sqrt{2} \cdot 120) = 679$ V peak.

A fast impulse applied to one conductor will tend to couple to the other nearby conductors as it travels. Its amplitude and rise time will also decrease as it travels. By the time that an impulse travels more than 20 or 30 ft, it is likely that there will be considerable common mode signal in the conductor bundle unless the signal started as a balanced signal over a balanced line (equal positive and negative pulse signals on each of a balanced wire pair). In many sensitive electronic units, common mode impulses and high-frequency noise from power source disturbances are a major cause of malfunctions. Isolating transformers placed close to the electronic equipment and the physical routing of grounding conductors to minimize intersection of power and low-voltage level signal ground paths will often reduce or eliminate power-related transient noise problems.

Electrical noise can have much the same effect as impulses upon sensitive electronic equipment and requires similar measures to cope with it. In digital equipment, digital circuits generally operate in one of two (binary) states. Its circuits are relatively insensitive to external disturbances most of the time. However, at transition and clock times, a noise signal that otherwise could not influence a logic state might alter it and corrupt the signal. The statistical probability may be small but

still create sufficient trouble to make a computer operation unacceptable to a user. Impulses are generally discrete events, and if there are not too many of them in a day, they may escape notice as a cause of difficulty. Noise, on the other hand, may be more continuous or occur in bursts. Depending upon occurrence and intensity, noise may be a more severe disturbance in terms of the number and frequency of malfunctions it causes.

Noise may be random in frequency content, but is more likely to have a strong frequency structure, some components of which may be at high radio frequencies. If power and grounding conductor lengths coincide with wavelengths (or multiples of quarter wavelengths) of noise frequencies, resonant conditions may occur that will greatly amplify the noise signals.

Grounding is an essential part of power sources and their connections to loads. In addition to making ground conductors comply with local codes for safety to personnel (keeping exposed metal at ground potential) and providing low impedance return paths so that circuit protection will clear faults, grounding should also serve as a constant potential signal reference from one part of the grounding system to another over a broad frequency range.

For much electrical equipment, 70–90% voltage protection is adequate, that is, transfer to emergency power when the line voltage drops to 70% of normal and retransfer when it returns to 90%. When specialized loads are used, the manufacturer's recommendations should be followed. For motor loads, the protection can be increased to provide 80–90% protection. Too close a voltage spread will cause many false or unnecessary transfers; too wide a spread will cause equipment damage and malfunctions. The length of time of the voltage dip is of paramount importance.

Justification of the expenditures necessary to fulfill *user needs* for emergency and standby power systems falls into three broad classifications:

- (1) Mandatory installations to meet laws and regulations of federal, state, county, and city
- (2) Maintenance of the safety and health of people involved during a power failure
- (3) Increased profits due to fewer and shorter power failures

Power for the safety of personnel and to prevent pollution of the environment may become increasingly mandatory. A continual check of laws and regulations should be maintained to be current with the requirements. Public Law Number 91-596, Williams-Steiger Occupational Safety and Health Act of 1970 (OSHA) [25],³ may materially alter the electric power reliability and availability requirements as the full interpretation and application of its provisions are published.

Table 1 is a guide to state codes and regulations for emergency power systems in the United States. All the latest codes and regulations for the area in which the industrial or commercial facility is located must be consulted and followed.

³ The numbers in brackets correspond to those of the references listed at the end of this chapter; when preceded by B, they correspond to the bibliography at the end of this chapter.

Table 1
Codes for Emergency Power by States and Major Cities (Completed September 1984)

State/City	Does State/City Have Legislation?	Legislation Code Type?	Hospitals	Nursing Homes	Schools	Theaters (Public Gathering Places)	Office Buildings	Hotels	Apartment Buildings	Airports	Fire and Police Stations	Water Treatment Plants	Sewage Treatment Plants	All Public Buildings, State	All Public Buildings, Commercial	Applicable Government Agency	Smokeproof Enclosures in High-Rise Buildings
Alabama	Yes	4,6	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C	C	C	C,D	C,D	M,N,O	B
Birmingham	Yes	4,6	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C	C	C	C,D	C,D	Q,S	A,B
Mobile	Yes	1,4	A,C,D	A,C,D	C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C	C	C	C	C	S	
Alaska	Yes	1,3	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	A,C,D	M,P	B
Arizona	No																
Phoenix	Yes	1	A,C,D	A,C,D	C,D	C,D	C,D	C,D	A,C,D					C,D	C,D	O	
Arkansas	Yes	1,6	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	A,C,D	M	B
California	Yes	2,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	C,D	O,T	A
Anaheim	Yes	2,3,4,7	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	C,D	M,N,O,Q	
Berkeley	Yes	1,3	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	C,D	C,D	C,D	M,Q	
Fresno	Yes	3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D			C,D	C,D	O,S	B
Glendale	Yes	3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D			C,D	C,D	M,Q	B
Long Beach	Yes	3	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	M,O	B
Los Angeles	Yes	3,4,8	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	B,C,D	C,D	C,D	C,D	C,D	C,D	M,Q,S	B
Oakland	Yes	1,3,4,8	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,O	B
Pasadena	Yes	1,2,3,4	A,C,D	C,D	C,D	A,C,D	A,C,D	C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	O,Q	
San Diego	Yes	3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	S	B
San Francisco	Yes	3,4	A,C,D	A,C,D	C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	O	B
San Jose	Yes	4														M,S	
Santa Ana	Yes	3,4	A,C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	A,C,D	C,D				C,D	C,D	M,Q	B
Colorado	Yes	3,4	A,C,D	A,C,D	C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D				C,D	A,C,D	Q	B
Denver	Yes	4,8	A,C,D	A,C,D	C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D				C,D	C,D	P	A
Connecticut	Yes	2,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	M	
Hartford	Yes	2	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	M,R	
New Haven	Yes	1,2,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	M,Q	
Delaware	Yes	1,2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	C,D	M	A

NOTE: An explanation of the numbers and letters used is given at the end of the table (see p 42).
Table 1 courtesy of the Electrical Generating Systems Marketing Association (April 1975).

Table 1 (Continued)

State/City	Does State/City Have Legislation?	Legislation Code Type?	Hospitals	Nursing Homes	Schools	Theaters (Public Gathering Places)	Office Buildings	Hotels	Apartment Buildings	Airports	Fire and Police Stations	Water Treatment Plants	Sewage Treatment Plants	All Public Buildings, State	All Public Buildings, Commercial	Applicable Government Agency	Smokeproof Enclosures in High-Rise Buildings
District of Columbia	Yes	2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,Q	A
Florida	Yes	1,2,4,6	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,O	A
Jacksonville	Yes	8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	Q,S	
St Petersburg	Yes	1,4,7	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	U	
Tampa	Yes	1,4,7	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M	A
Georgia	Yes	1,4,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M	
Atlanta	Yes	1,4,7	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M	B
Columbus	Yes	1,4,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	O	
Savannah	Yes	4,6	A,C,D	B,C,D	B,C,D	B,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	S	
Hawaii	Yes	4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	S	B
Honolulu	Yes	1,3	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	C,D	C,D	C,D	C,D	M,Q	B
Idaho	Yes	1,3,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,Q	B
Illinois	Yes	1,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,R	B
Chicago	No	2	A,C,D	A,C,D	C,D	A,C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	B	A,C,D	A,C,D	A,C,D	M,N	
Rockford	Yes	8	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	S	
Indiana	Yes	1,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	S	B
Evansville	Yes	2,3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	M,Q,R	B
Fort Wayne	Yes	3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	Q	B
Gary	Yes	1,3,4	A,C,D	A,C,D	C,D	A,C,D	C,D	A,C,D	C,D	A,C,D	A,C,D	A,C,D	B,C,D	A,C,D	A,C,D	M,Q	B
Indianapolis	Yes	1,4	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	S	B
South Bend	Yes	2	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	A,C,D	A,C,D	S	B
Iowa	Yes	1,3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	M	B
Des Moines	Yes	1,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	M,Q	B
Kansas	Yes	3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	M,Q	B
Kansas City	Yes	1,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,Q	B
Wichita	Yes	4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,Q	B
Kentucky	Yes	1,2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M,O	B

NOTE: An explanation of the numbers and letters used is given at the end of the table (see p 42).

Table 1 (Continued)

State/ City	Does State/City Have Legislation?	Legislation Code Type?	Hospitals	Nursing Homes	Schools	Theaters (Public Gathering Places)	Office Buildings	Hotels	Apartment Buildings	Airports	Fire and Police Stations	Water Treatment Plants	Sewage Treatment Plants	All Public Buildings, State	All Public Buildings, Commercial	Applicable Government Agency	Smokeproof Enclosures in High-Rise Buildings
Louisiana	Yes	1,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	B		C,D	C,D	M,Q	
Baton Rouge	**	4	A,C,D	A,C,D	B,C,D	A,C,D	B,C,D	A,C	C	A,C,D	A,C,D			C,D	C,D	S	
New Orleans	Yes	4	A,C,D	A,C,D	C,D	C,D	A,C,D*	A,C,D*	C	C,D	C,D	C,D	B	C,D	C,D	S	
Shreveport	Yes	1,4	A,C,D	A,C,D	B,C,D	C,D	A,C,D	C,D	C,D	A,C,D	A,C,D	C,D	C,D	C,D	A,C,D	S	
Maine	Yes	1,2,4	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	C,D	M,S	A
Maryland	Yes	1,2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	M,N	A
Baltimore	Yes	4,8	A,C,D	C,D	C,D	A,C,D	C,D	A,C,D	C,D	C,D	A,C,D	C,D	C,D	C,D	C,D	S	
Massachusetts	Yes	2,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	C,D	C,D	C,D	C,D	P,Q	B
Bedford	**	2	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	S	
Boston	Yes	2	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D		A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	S	
Cambridge	Yes	2	A,B	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D		A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	S	
Springfield	Yes	2	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D		A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	Q	
Worcester	Yes	2	A,C	A,C	A,C	A,C	A,C	A,C	A,C	A,C	A,C			A,C	A,C	Q	
Michigan	Yes	2,4,5	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	A,C,D	C,D	B,C,D	B,C,D	C,D	C,D	R	B
Detroit	Yes	1,4,5	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	A,C,D	C,D	B,C,D	B,C,D	A,C,D	A,C,D	M,S	B
Flint	Yes	4,5	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	B,C,D	B,C,D	A,C,D	A,C,D	M,S	
Grand Rapids	Yes	1,4,5	A,C,D	A,C,D	A,C,D	A,C,D	C,D	A,C,D	A,C,D	C,D	C,D			C,D	C,D	M,S	B
Lansing	Yes	2	A,C,D	A,C,D	A,C,D	A,C,D	C,D	A,C,D	C,D	C,D	C,D	B	B	C,D	C,D	S	
Minnesota	Yes	2,3,4,7	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	M,N,O	B
Minneapolis	Yes	1,3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	M,S	B
Saint Paul	Yes	1,3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A	A,C,D	A,C,D	A,C,D	A,C,D	M,S	B
Mississippi	Yes	1,4,6	A,C,D	C,D	C,D	C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	M	
Jackson	Yes	1,4	A,C,D	C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	S	
Missouri	No																
Kansas City	Yes	4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D			C,D	C,D	M,Q	A
Montana	Yes	2,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D			C,D	C,D	M	
Nebraska	Yes	1,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D			C,D	C,D		

NOTE: An explanation of the numbers and letters used is given at the end of the table (see p 42).

Table 1 (Continued)

State/City	Does State/City Have Legislation?	Legislation Code Type?	Hospitals	Nursing Homes	Schools	Theaters (Public Gathering Places)	Office Buildings	Hotels	Apartment Buildings	Airports	Fire and Police Stations	Water Treatment Plants	Sewage Treatment Plants	All Public Buildings, State	All Public Buildings, Commercial	Applicable Government Agency	Smokeproof Enclosures in High-Rise Buildings
Lincoln	Yes	4,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D				A,C,D	C,D	M,S	A*
Omaha	Yes	4,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	S	
Nevada	Yes	1,2,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	M,O,Q	
New Hampshire	Yes	1,2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	M	A
New Jersey	Yes	2,3,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	Q	
New Mexico	Yes	1,2,3,4	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	A,C,D	C,D	C,D	C,D		A,C,D	Q	
Albuquerque	Yes	3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	S	A
New York	Yes	2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	O	
Albany	Yes	2,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	Q	
Buffalo	Yes	2,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	N,O,R	
New York	Yes	3,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	Q	B
Syracuse	Yes	2,4,6	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	M,Q	A
North Carolina	Yes	1,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	O,T	
North Dakota	Yes	2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	M,O	
Ohio	Yes	2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	Q,S	A
Akron	Yes	2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	O	A
Cincinnati	Yes	2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	Q,S	A
Cleveland	Yes	2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	M,Q	A
Dayton	Yes	2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	Q	A
Youngstown	Yes	2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	Q	A
Oklahoma	Yes ⁺	1,2	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	M	
Oregon	Yes	1,2,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	A,C,D	C,D	C,D		C,D	M,Q	B
Portland	Yes	1,2,4	A,C,D	C,D	C,D	C,D	C,D	C,D	A,C,D	C,D					C,D	M,Q	
Pennsylvania	Yes	1,2	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D				A,C,D	R	A
Philadelphia	Yes	4,8	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D		A,C,D	M,Q	A
Rhode Island	Yes	2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	M,Q	A
South Carolina	Yes	1,4,6	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D					C,D	M,O	

NOTE: An explanation of the numbers and letters used is given at the end of the table (see p 42).

⁺State buildings only.

Table 1 (Continued)

State/City	Does State/City Have Legislation?	Legislation Code Type?	Hospitals	Nursing Homes	Schools	Theaters (Public Gathering Places)	Office Buildings	Hotels	Apartment Buildings	Airports	Fire and Police Stations	Water Treatment Plants	Sewage Treatment Plants	All Public Buildings, State	All Public Buildings, Commercial	Applicable Government Agency	Smokeproof Enclosures in High-Rise Buildings
South Dakota	Yes	1,2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	C,D	M	A
Tennessee	Yes	1,4,6	A,C,D	A,C,D	C,D	C,D										M,N,O	
Texas	Yes	2	A,C,D	B,C,D												M,O,U	
Anarillo	Yes	8	A,C	A,C	C,D	C,D	C,D	C,D	C	A,C	A,C	A			C	O	
Austin	Yes	3	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	A,C	C,D				C,D	Q	
Corpus Christi	Yes	3	A,C,D	A,C,D	C,D	A,C,D	C,D	C,D	C,D	A,C,D	C,D				C,D	Q	
Dallas	Yes	3,4	A,C,D	A,C,D	C,D	A,C,D	C,D	A,C,D	A,C,D	C,D	C,D				C,D	S	
El Paso	Yes	4,6	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				A,C,D	S	A
Fort Worth	Yes	3,4	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	A,C,D				C,D	S	
Houston	Yes	3,4,8	A,C,D	A,C,D	C,D	C,D	B,C,D*	B,C,D*	B,C,D*	B,C,D*	B,C,D*				B,C,D*	S	
Lubbock	Yes	1,3,4	A,C,D	A,C,D	C,D	A,C,D	C,D	C,D	C,D	A,C,D	C,D				C,D	M,Q	B
San Antonio	Yes	4,8	A,C,D	A,C,D	C,D	A,C,D	C,D	C,D	C,D	C,D	C,D				C,D	M	
Wichita Falls	Yes	7	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	S	
Utah	Yes	1,2,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	M,Q	B
Salt Lake City	Yes	3,8	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	M,Q	
Vermont	Yes	1,2,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	R	A
Virginia	Yes	2,4,5	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	O	B
Richmond	Yes	1,4,5	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	O,Q	
Virginia Beach	Yes	4,5	A,C,D	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	A,C,D	B,C,D				C,D	Q	
Washington	Yes	2,3,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	R	B
Seattle	Yes	3,4	A,C,D	A,C,D	C,D	C,D	C,D	A,C,D	A,C,D	C,D	C,D				C,D	Q	
West Virginia	Yes	1,2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				A,B	M,O	
Wisconsin	Yes	2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	R,S	
Madison	Yes	2,4	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	O	
Milwaukee	Yes	2,4,8	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	Q	
Wyoming	Yes	1,2,3	A,C,D	A,C,D	A,C,D	C,D	C,D	C,D	C,D	C,D	C,D				C,D	M,N,P	

NOTE: An explanation of the numbers and letters used is given at the end of the table (see p 42).

Table 1 (Continued)

Explanation of Numbers and Letters Used in Table 1:	
Legislation Code Type	
1. Life Safety Code, ANSI/NFPA 101-1985 [11]	
2. State	
3. Uniform Building Code [24]	
4. National Electrical Code, ANSI/NFPA 70-1987 [9]	
5. Building Officials and Code Administration (BOCA)	
6. Standard Building Code [23]	
7. Health Care Facilities Code, ANSI/NFPA 99-1984 [10]	
8. City	
	Power Source
	A. Emergency Power
	B. Standby Power
	C. Exit Lighting
	D. Egress Lighting
	Governing Agency
	M. Fire Marshal or Division of Fire
	N. Department of Public Health
	O. Local Government Units
	P. Public Safety
	Q. Building Commission or Department
	R. Department of Labor
	S. Inspection Department
	T. Department of Insurance
	U. Various, but usually depends on occupancy

* High-rise building.

** No changes made since previous report.

Table 2 lists the needs in thirteen general categories with some breakdown under each to indicate major requirements. Ranges under the columns "Maximum Tolerance Duration of Power Failure" and "Recommended Minimum Auxiliary Supply Time" are assigned based upon experience. Written standards have been referenced where applicable.

In some cases, under the column "Type of Auxiliary Power System" both emergency and standby have been indicated as required. An emergency supply of limited time capacity may be used at a low cost for immediate or uninterruptible power until a standby supply can be brought on line. An example would be the case where battery lighting units come on until a standby generator can be started and transferred to the critical loads.

Following the table, the "General Need" listings are presented in greater detail with recommendations as to the type of equipment or system that should be used.

Users of this standard may wish to skip the detailed presentation of each "General Need" and go directly to Chapter 4, "Systems and Hardware." If so, care should be taken that all individual needs have been recognized and listed so that suitable power systems can be selected to meet all requirements.

Readers using this standard may find that various combinations of general needs will require an in-depth system and cost analysis that will modify the recommended equipment and systems to best meet the specific requirements.

Small commercial establishments and manufacturing plants will usually find their requirements under two or three of the general need guidelines given in this chapter. Large manufacturers and commercial facilities will find that portions or all of the need guidelines given here apply to their operations and justify or require emergency and backup standby electric power.

3.2 Lighting

3.2.1 Introduction. Evaluation of the quality, quantity, type, and duration of emergency or standby power for lighting is necessary for each particular application. The different types of systems have various degrees of reliability that must be considered in the selection of the proper system.

3.2.2 Lighting for Evacuation Purposes. Interruption of power to a normal lighting system may cause injury or loss of life. Emergency lighting for evacuation purposes must energize automatically upon loss of normal lighting. Where legally required (ANSI/NFPA 101-1985 [11]) emergency systems are installed, lighting must be maintained for at least 1½ h if battery-powered unit equipment is used. Emergency lighting must provide enough illumination to allow easy and safe egress from the area involved. All exit lights, signs, and stairwell lights should be included in both the emergency lighting system and the normal lighting system. Design of the emergency lighting system should include consideration of the need for lighting to silhouette protruding machines or objects in aisles.

3.2.3 Perimeter and Security Lighting. Emergency or standby power for perimeter and security lighting may be deemed necessary to reduce risk of injury, theft, or property damage. The power for perimeter lighting may not be required until several minutes after failure of normal power. In order to maintain perimeter lighting throughout the dark hours, a system should be capable of supplying power

Table 2
Condensed General Criteria for Preliminary Consideration

Section	General Need	Specific Need	Maximum Tolerance Duration of Power Failure	Recommended Minimum Auxiliary Supply Time	Type of Auxiliary Power System		System Justification
					Emergency	Standby	
3.2	Lighting	Evacuation of personnel	Up to 10 s, preferably not more than 3 s	2 h	×	×	Prevention of panic, injury, loss of life Compliance with building codes and local, state, and federal laws Lower insurance rates Prevention of property damage Lessening of losses due to legal suits
		Perimeter and security	10 s	10–12 h during all dark hours	×	×	Lower losses from theft and property damage Lower insurance rates Prevention of injury
		Warning	From 10 s up to 2 or 3 min	To return to prime power source	×		Prevention or reduction of property loss Compliance with building codes and local, state, and federal laws Prevention of injury and loss of life
	Restoration of normal power system		1 s to indefinite depending on available light	Until repairs completed and power restored	×	×	Risk of extended power and light outage due to a longer repair time
	General lighting		Indefinite; depends on analysis and evaluation	Indefinite; depends on analysis and evaluation		×	Prevention of loss of sales Reduction of production losses Lower risk of theft Lower insurance rates

Table 2 (Continued)

Section	General Need	Specific Need	Maximum Tolerance Duration of Power Failure	Recommended Minimum Auxiliary Supply Time	Type of Auxiliary Power System		System Justification
					Emergency	Standby	
3.3	Startup power	Hospitals and medical areas	Uninterruptible to 10 s ANSI/NFPA 99-1984 [10], 101-1985 [11] allow 10 s for alternate power source to start and transfer	To return of prime power	×	×	Facilitate continuous patient care by surgeons, medical doctors, nurses, and aids Compliance with all codes, standards, and laws Prevention of injury or loss of life Lessening of losses due to legal suits
		Orderly shutdown time	0.1 s to 1 h	10 min to several hours	×		Prevention of injury or loss of life Prevention of property loss by a more orderly and rapid shutdown of critical systems Lower risk of theft Lower insurance rates
		Boilers	3 s	To return of prime power	×	×	Return to production Prevention of property damage due to freezing Provision of required electric power
3.4	Transportation	Air compressors	1 min	To return of prime power		×	Return to production Provision for instrument control
		Elevators	15 s to 1 min	1 h to return of prime power		×	Personnel safety Building evacuation Continuation of normal activity
		Material handling	15 s to 1 min	1 h to return of prime power		×	Completion of production run Orderly shutdown Continuation of normal activity
		Escalators	15 s to no requirement for power	Zero to return of prime power		×	Orderly evacuation Continuation of normal activity

Table 2 (Continued)

Section	General Need	Specific Need	Maximum Tolerance Duration of Power Failure	Recommended Minimum Auxiliary Supply Time	Type of Auxiliary Power System		System Justification
					Emergency	Standby	
3.5	Mechanical utility systems	Conveyors	15 s to 1 min	As analyzed and economically justified		×	Completion of production run Completion of customer order Orderly shutdown Continuation of normal activity
		Water (cooling and general use)	15 s	½ h to return of prime power		×	Continuation of production Prevention of damage to equipment Supply of fire protection
		Water (drinking and sanitary)	1 min to no requirement	Indefinite until evaluated		×	Providing of customer service Maintaining personnel performance
		Boiler power	0.1 s	1 h to return of prime power	×	×	Prevention of loss of electric generation and steam Maintaining production Prevention of damage to equipment
3.6	Heating	Pumps for water, sanitation, and production fluids	10 s to no requirement	Indefinite until evaluated		×	Prevention of flooding Maintaining cooling facilities Providing sanitary needs Continuation of production Maintaining boiler operation
		Fans and blowers for ventilation and heating	0.1 s to return of normal power	Indefinite until evaluated	×	×	Maintaining boiler operation Providing for gas-fired unit venting and purging Maintaining cooling and heating functions for buildings and production
		Food preparation	5 min	To return of prime power		×	Prevention of loss of sales and profit Prevention of spoilage of in-process preparation

Table 2 (Continued)

Section	General Need	Specific Need	Maximum Tolerance Duration of Power Failure	Recommended Minimum Auxiliary Supply Time	Type of Auxiliary Power System		System Justification
					Emergency	Standby	
3.7	Refrigeration	Process	5 min	Indefinite until evaluated; normally for time for orderly shut-down, or to return of prime power	×		Prevention of in-process product damage Prevention of property damage Continued production Prevention of payment to workers during no production Lower insurance rates
		Special equipment or devices which have critical warmup (cryogenics)	5 min	To return of prime power	×		Prevention of equipment or product damage
		Depositories of critical nature (blood banks, etc)	5 min (10 s per ANSI/NFPA 99-1984 [10])	To return of prime power	×		Prevention of loss of material stored
3.8	Production	Depositories of noncritical nature (meat, produce, etc)	2 h	Indefinite until evaluated	×		Prevention of loss of material stored Lower insurance rates
		Critical process power (sugar factory, steel mills, chemical processes, glass products, etc)	1 min	To return of prime power or until orderly shut-down	×		Prevention of product and equipment damage Continued normal production Reduction of payment to workers on guaranteed wages during nonproductive period Lower insurance rates Prevention of prolonged shut-down due to nonorderly shut-down

Table 2 (Continued)

Section	General Need	Specific Need	Maximum Tolerance Duration of Power Failure	Recommended Minimum Auxiliary Supply Time	Type of Auxiliary Power System		System Justification
					Emergency	Standby	
3.9	Space conditioning	Process control power	Uninterruptible (UPS) to 1 min	To return of prime power	×	×	Prevention of loss of machine and process computer control program Maintaining production Prevention of safety hazards from developing Prevention of out-of-tolerance products
		Temperature (critical application)	10 s	1 min to return of prime power	×	×	Prevention of personnel hazards Prevention of product or property damage Lower insurance rates Continuation of normal activities Prevention of loss of computer function
		Pressure (critical) pos/neg atmosphere	1 min	1 min to return of prime power	×	×	Prevention of personnel hazards Continuation of normal activities Prevention of product or property damage Lower insurance rates Compliance with local, state, and federal codes, standards, and laws
		Humidity (critical)	1 min	To return of prime power	×	×	Prevention of loss of computer functions Maintenance of normal operations and tests Prevention of explosions or other hazards

Table 2 (Continued)

Section	General Need	Specified Need	Maximum Tolerance Duration of Power Failure	Recommended Minimum Auxiliary Supply Time	Type of Auxiliary Power System		System Justification
					Emergency	Standby	
		Static charge	10 s or less	To return of prime power	×	×	Prevention of static electric charge and associated hazards Continuation of normal production (printing press operation, painting spray operations)
		Building heating and cooling	30 min	To return of prime power		×	Prevention of loss due to freezing Maintenance of personnel efficiency Continuation of normal activities
		Ventilation (toxic fumes)	15 s	To return of prime power or orderly shutdown	×	×	Reduction of health hazards Compliance with local, state, and federal codes, standards, and laws
		Ventilation (explosive atmosphere)	10 s	To return of prime power or orderly shutdown	×	×	Reduction of explosion hazard Prevention of property damage Lower insurance rates Compliance with local, state, and federal codes, standards, and laws
		Ventilation (building general)	1 min	To return of prime power		×	Lower hazard of fire Reduce hazards to personnel Maintaining of personnel efficiency Providing make-up air in building