

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

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**Abstract:** This Recommended Practice addresses the uses, power sources, design, and maintenance of emergency and standby power systems. Chapter Chapter 3 is a general discussion of needs for and the configuration of emergency and standby systems. Chapter Chapter 9 lists the power needs for specific industries. Chapters 4 and 5 deal with selection of power sources. Chapter Chapter 6 provides recommendations for protecting both power sources and switching equipment during fault conditions. Chapter Chapter 7 provides recommendations for design of system grounding, and Chapter Chapter 10 provides recommendations for designing to reliability objectives. Chapter Chapter 8 provides recommended maintenance practices.

**Keywords:** batteries, emergency generators, emergency power, emergency system, emergency system design, engine generators, standby power, standby system, stored energy systems, transfer switch, uninterruptible power supplies, UPS, UPS batteries

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## Introduction

(This introduction is not a part of IEEE Std 446-1995, 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 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 causes 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 existing working group was changed to the status of a subcommittee under the Industrial and Commercial Power Systems Committee to have direct

responsibility, not only for the Orange Book Working Group, but for other matters concerning emergency and standby power. The proposed publication was redirected toward establishing recommended practices. As a result of subsequent organizational changes, this Emergency and Standby Power Systems Subcommittee is now under the Power Systems Engineering Committee of the Industrial and Commercial Power Systems Department.

This third revision of the IEEE Orange Book contains updating and expansion of existing material. In addition, a new chapter has been added that addresses design criteria for achieving reliability objectives.

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 Department:

- IEEE Std 141-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book).
- IEEE Std 142-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book).
- IEEE Std 241-1990, IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book).
- IEEE Std 242-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book).
- IEEE Std 399-1990, IEEE Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book).
- IEEE Std 493-1990, IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book).
- IEEE Std 602-1996, IEEE Recommended Practice for Electric Systems in Health Care Facilities (IEEE White Book).
- IEEE Std 739-1995, IEEE Recommended Practice for Energy Management in Industrial and Commercial Facilities (IEEE Bronze Book).
- IEEE Std 1100-1992, IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book).

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

## Chapter 1 Scope

This standard presents recommended engineering principles, practices, and guidelines for the selection, design, installation, application, operation, and maintenance of emergency and standby power systems. This information is primarily presented from a user's viewpoint; however, managing the effects of power system disturbances requires close cooperation between users, electric utilities, and equipment manufacturers.

This standard addresses the following questions:

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

Definitions to specialized technical terms used throughout this standard are provided in Chapter 2. Emergency and standby power requirements of both industrial and commercial users are outlined and discussed, including a distinction made between mandatory laws, regulations, codes, and standards applicable to each. Knowledge of these requirements enables electric utility companies to meet specific power supply needs and equipment manufacturers to design efficient, practical, and reliable equipment and systems. Recommendations are made for various types of installations, based on technical and economic information on available hardware and systems provided by equipment manufacturers.

Technical guidelines for protecting and grounding emergency and standby power systems are presented in Chapter 6 and Chapter 7, respectively. Guidelines for the maintenance of specific types of equipment are presented in Chapter 8. Chapter 9 provides information on applications of emergency and standby power for specific industries. Chapter 10 presents design and operation guidelines that will improve emergency and standby power system reliability.

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 provide terms and definitions applicable to this standard for the purpose of aiding in its overall understanding.

NOTE—The definitions of **emergency power system** and **standby power system** contained herein are based on the general functions of the two systems. They may not agree entirely with definitions developed by other bodies, which establish specific operating criteria or are used to establish regulatory codes.

#### 2.2 Terms

**2.2.1 absorbed electrolyte cell:** A valve-regulated lead-acid (VRLA) cell whose electrolyte has been immobilized in absorbent separator (normally, glass or polymeric fiber). *Syn:* **starved electrolyte cell; absorbed glass mat (AGM) cell.**

**2.2.2 absorbed glass mat (AGM) cell:** *See:* **absorbed electrolyte cell.**

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

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

**2.2.5 battery:** Two or more cells electrically connected for producing electric energy.

NOTE—Also commonly used to apply to a single cell used independently.

**2.2.6 battery rack:** A structure used to support a group of cells.

**2.2.7 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.

**2.2.8 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.

**2.2.9 current withstand rating:** The maximum allowable current, either instantaneous or for a specified period of time, that a device can withstand without damage, or without exceeding the criteria of an applicable safety or performance standard.

**2.2.10 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.

**2.2.11 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.

**2.2.12 flooded cell:** *See: vented cell.*

**2.2.13 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.

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

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

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

**2.2.16 gel cell:** *See: gelled electrolyte cell.*

**2.2.17 gelled electrolyte cell:** A valve-regulated lead-acid (VRLA) cell whose electrolyte has been immobilized by the addition of a gelling agent. *Syn: gel cell.*

**2.2.18 harmonic content:** A measure of the presence of harmonics in a voltage or current wave form 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).

**2.2.19 immobilized electrolyte:** Electrolyte in a cell that is retained by either using gelled or absorbed electrolyte technology.

**2.2.20 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.

**2.2.21 oxygen index:** The minimum concentration of oxygen, expressed as volume percent, in a mixture of oxygen and nitrogen that will just support flaming combustion of a material initially at room temperature, referred to in battery manufacturers' flammability designations for battery cases. *Syn: limiting oxygen index (LOI).*

**2.2.22 limiting oxygen index (LOI):** *See: oxygen index.*

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

**2.2.24 power outage:** Complete absence of power at the point of use.

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

**2.2.26 prime power:** The 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.

**2.2.27 rated capacity (battery):** The manufacturer's statement of the number of ampere-hours or watt-hours that can be delivered by a fully charged battery at a specific discharge rate and electrolyte temperature, to a given end-of-discharge voltage.

**2.2.28 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.

**2.2.29 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.

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

**2.2.31 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.

**2.2.32 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.

**2.2.33 starved electrolyte cell:** *See: absorbed electrolyte cell.*

**2.2.34 transient:** That part of the change in a variable, such as voltage, current, or speed, which may be initiated by a change in steady-state conditions or an outside influence, that decays and/or disappears following its appearance.

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

**2.2.36 valve-regulated lead-acid (VRLA) cell:** A lead-acid cell that is sealed with the exception of a valve that opens to the atmosphere when the internal gas pressure in the cell exceeds atmospheric pressure by a pre-selected amount.

**2.2.37 vented cell:** A cell design that is characterized by an excess of free electrolyte, and in which the products of electrolysis and evaporation can freely exit the cell through a vent. *Syn:* **flooded cell; wet cell.**

**2.2.38 wet cell:** *See:* **vented cell.**

## 2.3 Bibliography

Additional information may be found in the following sources:

[B1] IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).<sup>1</sup>

[B2] Migliaro, M.W., and Alber, G., editors, "Glossary of Stationary Battery Terminology," Alber Technologies, Inc., Boca Raton, FL, 1992.

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<sup>1</sup>IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

## Chapter 3

### General need guidelines

#### 3.1 Introduction

While all who use electric power desire perfect frequency, voltage stability, and reliability at all times, this cannot be realized in practice because of the many causes of power supply disturbances that are beyond the control of the utility. For example, power failures can be caused by automobiles hitting poles; animals climbing across insulators; lightning striking overhead lines; and high winds blowing tree branches and other debris into lines.

The lightning, wind, and rain produced by thunderstorms and tornadoes can also cause power interruptions and transients. Figures 3-1 and 3-2 are both useful in determining the probability of such power failures (from thunderstorms and from tornadoes, respectively) depending upon the user's geographic location. More widely located storms, such as hurricanes, snowstorms, ice storms, and floods, also take their toll on power supply systems.

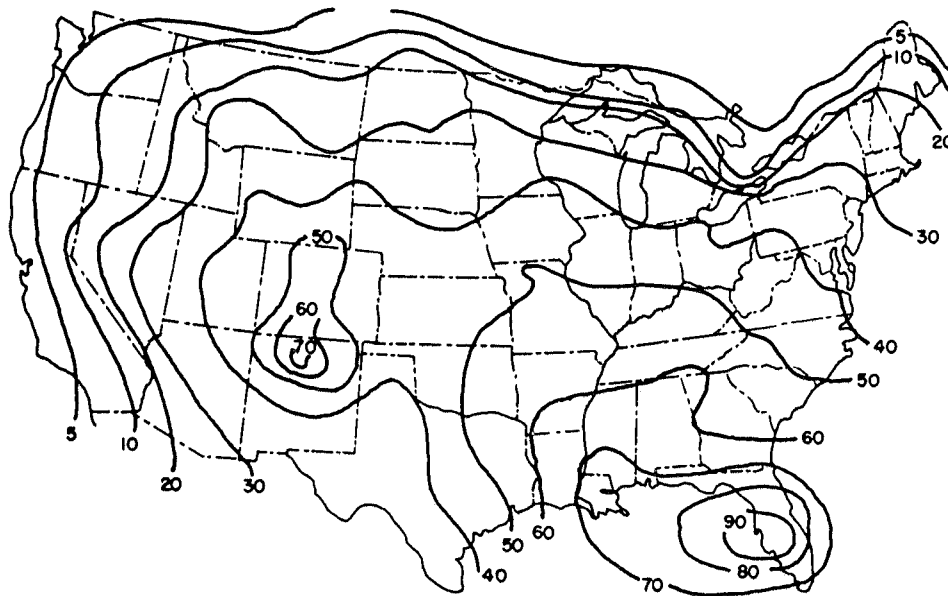


**Figure 3-1—Average number of thunderstorm days per year**

Although there is less chance for a power interruption caused by severe weather or other natural phenomena occurring 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

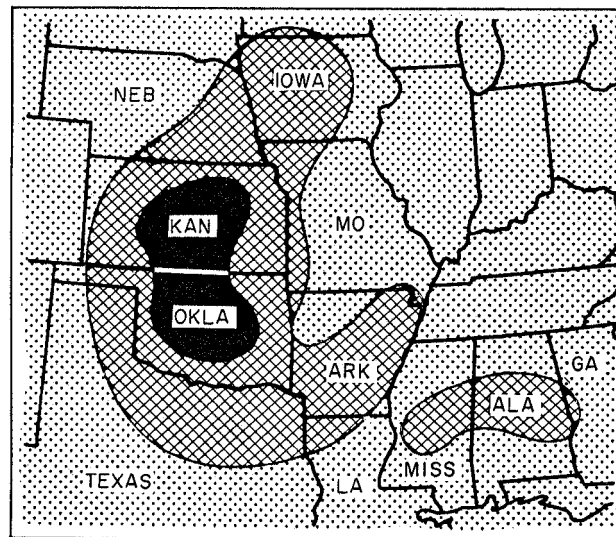


**Figure 3-2—Approximate density of tornadoes;  
cross-hatched areas—100–200 in 40 years;  
black area—over 200 in 40 years  
(see 3.15, Standard Building Code)**

the greater length of time required to discover the source of the cable failure 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 are 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.

Since utility companies have little practical control over disturbances on their systems, they are unwilling to accept responsibility for them or to make power quality or continuity guarantees. The following disclaimer is 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 voltage of 208/120 V wye. 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.”

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.

Any meaningful data with regard to power quality, or lack of it, will become 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.

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 reliable 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.

The following list describes methods that can be used to reduce to acceptable limits, or even eliminate, the effects of power supply disturbances:

- Modification of the design of utilization equipment so as to be impervious to power disturbances and discontinuities;
- Modification of the prime power distribution system to be compatible with utilization equipment;
- Modification of both systems and equipment to meet a criterion that is realistic for both;
- 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 ac 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 paragraph. 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 initially fast voltage rise or fall (sometimes oscillatory) followed by a slower voltage rise or fall. Thus one transient event may contain both fast impulses and 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.

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 measurements will make problem-solving easier and in some cases will help identify the source of the disturbances.

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

- a) Voltage
  - 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).

- b) Wave shape
- c) Frequency
- d) Phase relationships

The steady-state value is measured with a true rms-actuated, rms-reading voltmeter or the equivalent. The instrument should be damped; otherwise the readings should 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. Rolling blackouts in central Florida during the disastrous freeze of December 1989 extended beyond the maximum 20 min and resulted in severe damage to crops and tropical fish hatcheries.

Unequal loading on polyphase lines or single-phase three-wire lines is often the cause of voltage unbalance. 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 unbalance. Selection of a delta-connected primary with 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.

### **3.1.1 Short-duration disturbances**

Most disturbances on a power system are of short duration. Studies show that 90% are less than one second. Voltage disturbances of more than once cycle duration are usually expressed in rms value. Those of less than once cycle are expressed in terms of the fundamental peak value. Subclauses 3.1.1.1–3.1.1.3 group disturbances according to their duration, usual description, and possible causes.

#### **3.1.1.1 Less than 1 cycle—transient**

Transients result from disturbances of all kinds. The most severe subcycle disturbances are natural lightning, electrostatic discharge, load switch, and short-duration faults.

#### **3.1.1.2 Half cycle to a few seconds—swell or sag**

Swells (increased voltage) or sags (decreased voltage) usually result from faults on the system with subsequent fuse or high-speed circuit breaker action and reclosing. On the loaded phases this results in a sag. On the unloaded phases the result may be a swell.

#### **3.1.1.3 More than a few seconds—overvoltage or undervoltage**

Overvoltage and undervoltage, usually attributed to severe faults accompanied by 50–100% voltage loss on one or more phases, often result in an outage in some circuit. Faults often involve all three phases and may be the result of a downed pole, a tree, or a crane on the line, a breaker lockout, or an in-line fuse blowing. If the critical load is on the cleared side of the fuse, 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 Frequency disturbances**

In large power systems frequency changes are rare. However, with small engine generators, used for emergency supply, some frequency change is unavoidable when blocks of load are switched. With a modern synchronous governor, these disturbances should be under 5% frequency change and less than 5 s duration, even for full load switching.

IEEE Std 1100-1992<sup>1</sup> contains additional information on short-duration disturbances.

<sup>1</sup>Information on references can be found in 3.15.

### 3.1.3 Grounding

Grounding is an essential part of power systems and their connections to loads. Grounding ensures safety for personnel, provides a low-impedance return path, and serves as a constant potential signal reference. Chapter 7 contains the specific features of grounding emergency systems.

### 3.1.4 Single-phasing

System designers need to be aware that some systems can fail to properly respond to failure of one phase on a three-phase system. Two conditions that may cause improper sensing are three-phase motors that continue to run single-phase and ferroresonance.

Three-phase motors may continue to run when one phase of a three-phase system fails. Under that condition, the motor will induce a voltage on the failed phase so that the transfer switch sensing circuit may not detect the phase loss. However, this may cause the motor to overheat. To avoid this problem, one approach is to use negative sequence sensors on the motor and disconnect it. Another approach is to use close-differential voltage relays (approximately 95% voltage pickup and 90% dropout) on all three phases in the transfer switch control.

Ferroresonance is a condition that can induce a flash voltage on a disconnected leg of a transformer. This condition can cause improper recycling of emergency or standby system transfer switches. In a known case, the opening of a single utility supply fuse caused the transfer switch to recycle continuously. Since the transfer switch switched all the load to the emergency supply, the normal supply transformer was left with zero load. Ferroresonance produced an rms voltage approximately equal to the normal voltage on the open leg of the unloaded transformer. Therefore, the transfer switch sensed that normal voltage had returned, and it switched back to normal.

The cause of ferroresonance is the magnetizing reactance of the transformer combined with open line capacitance. The transformer was 225 kVA three-phase with grounded-wye primary/grounded-wye secondary. The connection between the transformer and the fuses was 25 kV #1 AWG cable of approximately 130 ft in length. Known practice indicates that these parameters do not produce ferroresonance in the heavily saturated region with associated damaging overvoltages. However, analysts have predicted distorted but nondamaging voltages on the open leg with 1.0–1.3 PU peak values (Smith, Swanson, and Borst 1975 [B18]).<sup>2</sup> The distortion from a sine wave is due to nonlinear (saturated) magnetic circuits.

In the above case, permanent resistive load on the transformer of slightly more than 1% of the rating, reduced voltages to well below the pickup point of the normal voltage-sensing relays on the transfer switch. Moving the transformer near the fuses (very short cable) also corrected the problem.

<sup>2</sup>The numbers in brackets preceded by the letter B correspond to those of the bibliography in 3.16.

Recommended practice for systems where single-phase switching, including fuse operation, can occur, is to maintain a small amount of untransferred load on the transformer secondary. Refer to IEEE Std 141-1993 for more information on industrial system connections.

### 3.1.5 Emergency power

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

- a) Mandatory installations to meet federal, state, county, and municipal regulations;
- b) Maintenance of the safety of people during a power failure;
- c) Decreased economic losses due to fewer and shorter power failures.

Mandatory regulations for alternate power sources to ensure the safety of personnel and to prevent pollution of the environment continually increase. The National Electrical Code® (NEC®) (NFPA 70-1996) contains regulations for the safe installation of emergency and standby power systems. NFPA 99-1996, ANSI/NFPA 110-1993, and ANSI/NFPA 111-1993 contain testing, performance, and maintenance requirements. ANSI/NFPA 101-1994 lists occupancies that require emergency power. Those requirements usually concern the safety of occupants. Government authorities may adopt building codes and other regulations that make such systems mandatory.

Table 3-1 is a guide to codes and enforcement agencies for states and major cities in the USA. The enforcement agencies for each project should be consulted before and during the design to make sure that current applicable regulations are complied with.

Table 3-2 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 in which battery lighting units come on until a standby generator can be started and transferred to the critical loads.

Following table 3-2, items from the “General need” column are presented in greater detail with recommendations as to the type of equipment or system that should be used (see 3.2–3.14).

Users of this standard may wish to skip the detailed presentation of each “General need” and go directly to Chapter 4. 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.

Table 3-1—Codes of states and major cities

| Building         | Electrical  | Life safety        | Enforcement                                                                              | Phone          |
|------------------|-------------|--------------------|------------------------------------------------------------------------------------------|----------------|
| Alabama          | NEC         | NFPA 101           | State Fire Marshal's Office, PO Box 303352, Montgomery, AL 36130-3352                    | (205) 269 3575 |
| Birmingham       | NEC amend   | NFPA 101           | Chief Electrical Inspector, City Hall, Rm 207, 710 N. 20th St., Birmingham, AL 35203     | (205) 254-2219 |
| Alaska           | NEC         | None               | State Fire Marshal, 5700 E. Tudor St., Anchorage, AK 99507-1225                          | (907) 269-5604 |
| Anchorage        | NEC         | None               | Building Official, PO Box 196650, Anchorage, AK 99519-6650                               | (907) 786-8307 |
| Arizona          | NEC         | Ariz Fire Code     | Asst Fire Marshal, Dept of Bldg & Fire Safety, 1540 W VanBuren, Phoenix, AZ 85007        | (602) 255-4072 |
| Phoenix          | NEC         | Ref in Bldg & Fire | Assistant Director, Development Services Dept, 200 W Washington, Phoenix, AZ 85003       | (602) 262-6901 |
| Arkansas         | NEC         | NFPA 101           | Elec. Administrator, 10421 W Markham, Rm. 301, Little Rock, AR 72205                     | (501) 682-4500 |
| Little Rock      | NEC         | None               | Dept of Neighborhood Planning, 723 W Markham St, Little Rock, AR 72201                   | (501) 371-4826 |
| California       | NEC amend   | None               | State Fire Marshal, 2171 Bowling Dr, Suite 600, Sacramento, CA 95823                     | (916) 262-1875 |
| Los Angeles      | NEC amend   | None               | Chief, Mechanical Bureau, Rm 485 City Hall, 200 N Spring St, Los Angeles, CA 90012       | (213) 485-2301 |
| San Diego        | NEC amend   | NFPA 101           | Dir Devel. Services Dept., 202 C St., MS9B, San Diego, CA 92101                          | (619) 236-6056 |
| San Francisco    | NEC amend   | None               | Ch Elec Insp, Dept of Building Insp, 1660 Mission St., San Francisco, CA 94103           | (415) 558-6030 |
| San Jose         | NEC supplmt | None               | Chief Inspector Dept of Planning, 801 N 1st St, Rm 200, San Jose, CA 95110               | (408) 277-4541 |
| Colorado         | NEC         | None               | Lester Fields, Div of Housing, 1313 Sherman St, RM 323, Denver, CO 80203                 | (303) 866-2033 |
| Denver           | NEC supplmt | NFPA 101           | Director, Building Inspection Div, 200 W 14th Ave, Denver, CO 80204-2700                 | (303) 640-5843 |
| Connecticut      | NEC amend   | NFPA 101 amend     | Public Safety Building Official, PO Box 2794, Middletown, CT 06457-9294                  | (203) 238-6011 |
| Delaware         | NEC         | NFPA 101 amend     | State Fire Marshal's Office, R.D. 2, Box 166A, Dover, DE 19901                           | (302) 739-4394 |
| Wilmington       | NEC         | NFPA 101 amend     | Dept Licenses & Inspection, 800 French St, 5th Floor, Wilmington DE 19801                | (302) 571-4423 |
| Dist of Columbia | NEC         | None               | Admr, Bldg & Land Regulation Adm, 614 H St NW, Room 312, Washington, DC 20001            | (202) 727-7340 |
| Florida          | NEC         | NFPA 101 amend     | Program Mgr, Dept of Community Affairs, The Rhyne Bldg., Tallahassee, FL 32399           | (904) 487-1824 |
| Jacksonville     | NEC         | NFPA 101           | Sup Elect Section, Room 100 City Hall, 220 E Bay St, Jacksonville, FL 32202              | (904) 630-1100 |
| Miami            | NEC w/excl  | NFPA 101           | Building Code Compliance Office, 140 W Flagler St, Suite 1603 Miami, FL 33130            | (305) 375-2901 |
| Orlando          | NEC amend   | NFPA 101           | Bldg Official, Bur of Code Enforcement, 400 S Orange Ave, Orlando, FL 32801              | (407) 246-2271 |
| Georgia          | NEC         | NFPA 101 amend     | Commis'nr, Dept Comm Affrs, 1200 Equitable Bldg, 100 Peachtree St, Atlanta, GA 30303     | (404) 656-5526 |
| Atlanta          | NEC amend   | NFPA 101 amend     | RL Dover, Electrical Division, 55 Trinity Av, SW, Suite 3900 Atlanta, GA 30335           | (404) 330-6180 |
| Hawaii           | None        | None               | Local                                                                                    |                |
| Honolulu         | NEC amend   | NFPA 101 limitd    | Glenn Yokomichi, Elect Engr , City/County Bldg Dept, 650 S King St, Honolulu, HI 96813   | (808) 527-6011 |
| Idaho            | NEC w/supl  | NFPA 101           | Elect Div Admr, Dept of Labor and Industrial Services, 277 N 6th, Boise, ID 83720        | (208) 334-2183 |
| Illinois         | NEC local   | NFPA 101           | State Fire Marshal, 1035 Stevenson Dr, Springfield, IL 62706                             | (217) 785-4714 |
| Chicago          | CEC         | None               | Chief Electrical Inspector, Dept of Buildings, 121 N LaSalle St, Chicago, IL 60602       | (312) 744-3457 |
| Indiana          | NEC amend   | None               | St Fire Marshal, Dept of Bldg Services, 402 W Washington St, Indianapolis, IN 46204      | (317) 232-2226 |
| Indianapolis     | NEC amend   | None               | Dir. Tech. Services and Research Div, 402 W Washington St, Indianapolis, IN 46204        | (317) 232-1402 |
| Iowa             | NEC amend   | Iowa Fire M Rules  | State Building Code Bureau, Wallace State office Building, Des Moines, IA 50319          | (515) 281-3992 |
| Des Moines       | NEC         | None               | Ed McAtee, Senior Elect Inspector, Building Dept, 602 E 1st St, Des Moines, IA 50309     | (515) 283-4925 |
| Kansas           | NEC         | NFPA 101 amend     | Ed Redmon, KS Fire Marshall., 700 SW Jackson St, Ste 600, Topeka, KS 66603-3714          | (913) 296-3401 |
| Wichita          | NEC amend   | NFPA 101           | Supr Central Inspection, 455 N Main St, Wichita, KS 67202                                | (316) 268-4460 |
| Kentucky         | NEC         | NFPA 101 (KYBC)    | State Fire Marshal, The 127 Building, 1047 US 127 S, Frankfort, KY 40601                 | (502) 564-3626 |
| Louisiana        | NEC         | NFPA 101           | Chief Architect, State Fire Marshal's Office, 5150 Florida Blvd, Baton Rouge, LA 70806   | (504) 925-4920 |
| New Orleans      | NEC amend   | NFPA 101           | Dir, Dept of Saf and Permits, Rm 7E05 City Hall, 1300 Perdido St, New Orleans, LA 70112  | (504) 565-6111 |
| Maine            | NEC         | NFPA 101           | Admr Electrician Exam Bd Licenc & Enforce, State House Station # 35, Augusta ME 04333    | (207) 582-8723 |
| Baltimore        | NEC         | NFPA 101 amend     | Ch Fire Prot Eng, Off St Fire Marshall, 101 Old Court Rd, Ste 300, Pikesville, MD 21032  | (410) 764-4324 |
| Massachusetts    | NEC amend   | NFPA 101           | Dennis Chojnowski, Permit Enforc, 417 E Fayette St, Rm 101, Baltimore, MD 21202          | (410) 396-3462 |
| Boston           | NEC         | NFPA 101 limitd    | Bd of Bldg Regulations, One Ashburton Place, Rm 1301, Boston, MA 02108                   | (617) 727-3200 |
| Michigan         | NEC amend   | NFPA 101 limitd    | Buildings and Inspectional Serv, 1010 Massachusetts Av, Boston, MA 02115                 | (617) 635-5300 |
| Detroit          | NEC         | None               | Ch Elec Div, Bur of Construction Codes, 7150 Harris Dr, PO Box 30254, Lansing MI 48909   | (517) 322-1739 |
| Minnesota        | NEC amend   | Ref NFPA 101       | Head Engr, Mech. Elect. Div, 434 City/County Bldg, 2 Woodward Av, Detroit, MI 49226      | (313) 224-3181 |
| Minneapolis      | NEC         | None               | St Bd of Electricity, Griggs Midway Bldg #S-128, 1821 University Av, St Paul, MN 55104   | (612) 642-0800 |
| Mississippi      | NEC         | None               | Supvr, Inspections Div, 300 Public Health Center, 250 S 4th St, Minneapolis, MN 55415    | (612) 673-5845 |
| Jackson          | NEC         | NFPA 101 limitd    | St Bldgs only - Dir Office of Bldgs & Grnds, 1501 Walter Sillers Bldg, Jackson, MS 39201 | (601) 359-3621 |
|                  | NEC         | None               | Charles Dezrow, Deputy Dir, Bldg Permit Div, PO Box 17, Jackson, MS 39205                | (601) 960-1159 |

Table 3-1—Codes of states and major cities (Continued)

| Building       | Electrical     | Life safety     | Enforcement                                                                                 | Phone          |
|----------------|----------------|-----------------|---------------------------------------------------------------------------------------------|----------------|
| Missouri       | NBC St Facil   | NFPA 101 St Fac | Office of Adm, Dept of Design & Construction, PO Box 809, Jefferson City, MO 65102          | (314) 751-4191 |
| Kansas City    | NBC amend      | None            | Director Codes Administration, 18th Floor City Hall, 414 E 12th St, Kansas City, MO 64106   | (816) 274-1464 |
| St. Louis      | NBC amend      | None            | Supt. Electrical Section, Building Dept, Rm 425, 1200 Market St, St. Louis, MO 63103        | (314) 622-3326 |
| Montana        | UBC amend      | None            | Bureau Chief Bldg Codes Bureau, Dept of Commerce, PO Box 200517 Helena, MT 59620            | (406) 444-3933 |
| Nebraska       | UBC amend      | NFPA 101 amend  | Terry Carlson, Exec Dir, State Electrical Bd, 800 S 13th St, RM 109, Omaha, NB 68102        | (402) 471-3550 |
| Omaha          | UBC amend      | NFPA 101 amend  | John Jesse, Superintendent, Permits and Inspection, 1819 Farnam St, Omaha, NB 68183         | (402) 444-5350 |
| Nevada         | UBC amend      | NFPA 101 ref    | Bruce Nipp, Sr Public Works Bd, Capitol Complex 505 E King St, Carson City, NV 89710        | (702) 687-3981 |
| Las Vegas      | UBC amend      | NFPA 101        | John Tucker, Director Building and Safety, 400 E Stewart Av, Las Vegas, NV 89101            | (702) 229-6251 |
| New Hampshire  | NBC            | NFPA 101 amend  | State Fire Marshal, Dept of Safety, 10 Hazen Dr, Concord, NH 03305                          | (603) 271-3294 |
| New Jersey     | NBC            | None            | Dept Comm Affrs, Div of Housing and Devel, 101 S Broad St, CN 802, Trenton, NJ 08625        | (609) 292-7899 |
| New Mexico     | UBC amend      | None            | R. Pacheco, act. Bureau Chief, Electrical Bureau, 725 St. Michael's Dr, Santa Fe, NM 87504  | (505) 827-7036 |
| Albuquerque    | UBC amend      | None            | D Steele, Ch Bldg Official, Codes Administration, 600 2nd St NW, Albuquerque, NM 87102      | (505) 764-1626 |
| New York       | U Fire & Bldg  | U Fire & Bldg   | Carl Sager, Director, Codes Division, Dept of State, 162 Washington Av, Albany, NY 12231    | (518) 474-4073 |
| Buffalo        | NY Fire & Bldg | NY Fire & Bldg  | David Piotrowicz, Ch Elec Inspector, City Hall, Rm 601, 65 Niagara St, Buffalo, NY 14202    | (716) 851-5902 |
| New York City  | NY City Bldg   | None            | M Kahane, PE, Dir, Bur of Elec Contr, Rm 2324 Mun Bldg, 1 Center St, New York, NY 10007     | (212) 669-8338 |
| North Carolina | SBC amend      | None            | Alan Barringer, Ch Elect Engr, Dept of Insurance, 410 N Boylan Av, Raleigh, NC 27611        | (919) 733-3901 |
| North Dakota   | UBC            | NFPA 101        | Richard Haman, Exec Dir Electrical Board, 721 Memorial Highway, Bismark, ND 58504           | (701) 328-2822 |
| Ohio           | NBC amend      | None            | Elmer Waltz, Div of Factory Bldg Insp, 2323 W 5th Av, PO Box 825, Columbus, OH 43216        | (614) 644-2622 |
| Cincinnati     | NBC amend      | NFPA 101        | Bob Lack, Ch Elec Insp, Dept Bldg & Insp, City Hall, Rm 316, Cincinnati, OH 45202           | (513) 381-6080 |
| Cleveland      | NBC amend      | None            | Ron Jennings, Ch Insp, Div of Bldg and Housing, 601 Lakeside Av, Cleveland, OH 44144        | (216) 664-2618 |
| Columbus       | NBC amend      | None            | Dan Benninger, Ch Elec Insp, Regulation Div, 1250 Fairwood Av, Columbus, OH 43206           | (614) 645-6076 |
| Oklahoma       | NBC            | NFPA 101 amend  | Office State Fire Marshal, 4545 N Lincoln Blvd, Suite 280, Oklahoma City, OK 73105          | (405) 524-9610 |
| Oklahoma City  | NBC amend      | NFPA 101        | RL Hood, Supt Insp Serv, Public Works Dept 420 W Main 8th Fl, Oklahoma City, OK 73109       | (405) 297-2948 |
| Oregon         | UBC amend      | None            | Junior Owings, Ch Elect Insp, Bldg Codes Div, 1535 Edgewater St NW, Salem, OR 97310         | (503) 373-7509 |
| Pennsylvania   | None           | State           | Director, Bur Occup, & Industrial Safety, Rm 1529 7th & Forester St, Harrisburg, PA 17120   | (717) 787-3323 |
| Philadelphia   | NBC amend      | None            | Ch Const Services, Dept of Lic & Insp, 11th Fl, 1401 JFK Blvd, Philadelphia, PA 19103       | (215) 686-5160 |
| Pittsburgh     | NBC amend      | None            | Chief Bur Bldg Inspection, Dept of Public Safety, 200 Ross St, Pittsburgh, PA 15220         | (412) 255-2176 |
| Rhode Island   | NBC amend      | None            | J Cirillo, Commissioner, State Bldg Comm, 1 Capitol Hill, 2nd Floor, Providence, RI 02908   | (401) 277-3529 |
| South Carolina | SBC            | None            | Asst Dep Dir, Build Codes & Related Services, 3600 Forest Dr, Suite 100, Columbia, SC 29201 | (803) 734-4182 |
| Charleston     | SBC            | None            | Building & Fire Official, 75 Calhoun St, Division 320, Charleston, SC 29401                 | (803) 724-7431 |
| South Dakota   | UBC amend      | NFPA 101        | Exec Dir, State Electrical Commission, 302 S Paunee Ave, Pierre, SD 57501                   | (605) 773-3573 |
| Tennessee      | SBC            | NFPA 101        | Elect Sec, Dept of Comm & Ins, Vol Pl, 3rd Fl, 500 J Robertson Pkwy, Nashville, TN 37243    | (615) 741-7170 |
| Memphis        | SBC amend      | None            | Bldg Off, Memphis/Shelby Cnty Code Enfor, 160 N Main St, Rm 750, Memphis, TN 38103          | (901) 576-5341 |
| Nashville      | SBC amend      | NFPA 101        | Dir, Dept of Codes Adm, Metro Howard Bldg, 700 2nd Av S, Nashville, TN 37210                | (615) 862-6600 |
| Texas          | None           | NFPA 101 limit  | Dept of Lic & Reg, Policy & Stds Div, Box 12157, Capitol St, Austin, TX 78711               | (512) 463-7356 |
| Dallas         | UBC amend      | None            | Economic Dev Dept, Bldg Inspection Div, 320 E Jefferson Blvd, Room 105, Dallas, TX 75203    | (214) 948-4480 |
| El Paso        | SBC amend      | NFPA 101        | Ch Electrical Inspector, Public Inspection Dept, 2 Civic Center Plaza, El Paso, TX 79901    | (915) 541-4900 |
| Ft. Worth      | UBC amend      | None            | Asst Dir/Bldg Official, City Dept of Devel, 1000 Throckmorton St, Ft. Worth, TX 76102       | (817) 871-8025 |
| Houston        | UBC amend      | None            | Dept Public Works, Codes & Standards Group, PO Box 1562, Houston, TX 77251                  | (713) 754-0004 |
| San Antonio    | UBC amend      | NFPA 101        | Dir, Bldg Insp Dept, 114 W Commerce St, PO Box 839966, San Antonio, TX 78283                | (210) 287-8232 |
| Utah           | UBC amend      | NFPA 101 limit  | Dept of Commerce, Div of Occup & Prof Lic, PO Box 45805, Salt Lake City, UT 84145           | (801) 530-6731 |
| Salt Lake City | UBC amend      | None            | Sr Elect Inspector, Building & Housing Services, 451 S State St, Salt Lake City, UT 84111   | (801) 535-7752 |
| Vermont        | UBC amend      | NFPA 101 amend  | Ch Elect Insp, Dept of Labor and Industry, National Life Bldg, Dwr 20 Montpelier, VT 05620  | (802) 828-2106 |
| Virginia       | UBC amend      | None            | Assoc Dir, Code Enfor Office, Div of Bldg Regulation, 501 N 2nd St, Richmond, VA 23219      | (804) 371-7160 |
| Washington     | UBC amend      | None            | Ch Elect Inspector, Div of Bldg & Cons Safety Services, PO Box 44660, Olympia, WA 98504     | (360) 902-5269 |
| Seattle        | UBC amend      | None            | Prin Engr, Dept of Construction & Land Use, 710 2nd Av, Suite 700, Seattle, WA 98104        | (206) 233-3892 |
| West Virginia  | UBC amend      | NFPA 101 amend  | Deputy State Fire Marshal, State Capitol, 2100 Washington St, Charleston, WV 25305          | (304) 558-2191 |
| Wisconsin      | State BC       | None            | Div of Safety & Bldgs, PO Box 7969, 201 E Washington Av, Madison, WI 53707                  | (608) 266-3080 |
| Milwaukee      | UBC            | None            | Commissioner, Dept of Bldg Insp, 841 N Broadway Av, MB 1001, Milwaukee, WI 53202            | (414) 278-2542 |
| Wyoming        | UBC            | None            | Dept Fire Prevention & Electrical Safety, 1 W 25th St, Cheyenne, WY 82002                   | (307) 777-7119 |

Source: EGS-A: 109C-1994 [B4]

Table 3-2—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                                            | x                              |         | Prevention of panic, injury, loss of life<br>Compliance with building codes and local, state, and federal laws<br>Lower insurance rates<br>Prevention of property damage<br>Lessening of losses due to legal suits |
|         |              | Perimeter and security             | 10 s                                           | 10–12 h during all dark hours                  | x                              | x       | Lower losses from theft and property damage<br>Lower insurance rates<br>Prevention of injury                                                                                                                       |
|         |              | Warning                            | From 10 s up to 2 or 3 min                     | To return to prime power                       | x                              |         | Prevention or reduction of property loss<br>Compliance with building codes and local, state, and federal laws<br>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     | x                              | x       | 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 |                                | x       | Prevention of loss of sales<br>Reduction of production losses<br>Lower risk of theft<br>Lower insurance rates                                                                                                      |

Table 3-2—Condensed general criteria for preliminary consideration (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 |                                                                                                                                                                                                                       |
| 3.2<br>(Cont.) | Lighting (Cont.) | Hospitals and medical areas | Uninterruptible to 10 s (NFPA 99-1996, ANSI/NFPA 101-1994); allow 10 s for alternate power source to start and transfer | To return to prime power                  | x                              | x       | Facilitate continuous patient care by surgeons, medical doctors, nurses, and aids<br>Compliance with all codes, standards, and laws<br>Prevention of injury or loss of life<br>Lessening of losses due to legal suits |
|                |                  | Orderly shutdown time       | 0.1 s to 1 h                                                                                                            | 10 min to several hours                   | x                              |         | Prevention of injury or loss of life<br>Prevention of property loss by a more orderly and rapid shutdown of critical systems<br>Lower risk of theft<br>Lower insurance rates                                          |
| 3.3            | Startup power    | Boilers                     | 3 s                                                                                                                     | To return to prime power                  | x                              | x       | Return to production<br>Prevention of property damage due to freezing<br>Provision of required electric power                                                                                                         |
|                |                  | Air compressors             | 1 min                                                                                                                   | To return to prime power                  |                                | x       | Return to production<br>Provision for instrument control                                                                                                                                                              |

Table 3-2—Condensed general criteria for preliminary consideration (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 |                                                                                                                    |
| 3.4     | Transportation             | Elevators                       | 15 s to 1 min                               | 1 h To return to prime power              |                                | x       | Personnel safety<br>Building evacuation<br>Continuation of normal activity                                         |
|         |                            | Material handling               | 15 s to 1 min                               | 1 h To return to prime power              |                                | x       | Completion of production run<br>Orderly shutdown<br>Continuation of normal activity                                |
|         |                            | Escalators                      | 15 s to no requirement for power            | Zero To return to prime power             |                                | x       | Orderly evacuation<br>Continuation of normal activity                                                              |
| 3.5     | Mechanical utility systems | Water (cooling and general use) | 15 s                                        | 1/2 h To return to prime power            |                                | x       | Continuation of production<br>Prevention of damage to equipment<br>Supply of fire protection                       |
|         |                            | Water (drinking and sanitary)   | 1 min to no requirement                     | Indefinite until evaluated                |                                | x       | Providing of customer service<br>Maintaining personnel performance                                                 |
|         |                            | Boiler power                    | 0.1 s                                       | 1 h To return to prime power              | x                              | x       | Prevention of loss of electric generation and steam<br>Maintaining production<br>Prevention of damage to equipment |

**Table 3-2—Condensed general criteria for preliminary consideration (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<br>(Cont.) | Mechanical utility systems<br>(Cont.) | Pumps for water, sanitation, and production fluids | 10 s to no requirement                      | Indefinite until evaluated                                                                      |                                | x       | Prevention of flooding<br>Maintaining cooling facilities<br>Providing sanitary needs<br>Continuation of production<br>Maintaining boiler operation                                    |
|                |                                       | Fans and blowers for ventilation and heating       | 0.1 s to return of normal power             | Indefinite until evaluated                                                                      | x                              | x       | Maintaining boiler operation<br>Providing for gas-fired unit venting and purging<br>Maintaining cooling and heating functions for buildings and production                            |
| 3.6            | Heating                               | Food preparation                                   | 5 min                                       | To return to prime power                                                                        |                                | x       | Prevention of loss of sales and profit<br>Prevention of spoilage of in-process preparation                                                                                            |
|                |                                       | Process                                            | 5 min                                       | Indefinite until evaluated; normally for time for orderly shutdown, or To return to prime power |                                | x       | Prevention of in-process production damage<br>Prevention of property damage<br>Continued production<br>Prevention of payment to workers during no production<br>Lower insurance rates |

Table 3-2—Condensed general criteria for preliminary consideration (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 | Special equipment or devices which have critical warm-up (cryogenics)                         | 5 min                                       | To return to prime power                           |                                | x       | Prevention of equipment or product damage                                                                                                                                                                                                            |
|         |               | Depositories of critical nature (blood bank, etc.)                                            | 5 min (10 s per NFPA 99-1996)               | To return to prime power                           |                                | x       | Prevention of loss of material stored                                                                                                                                                                                                                |
|         |               | Depositories of noncritical nature (meat, produce, etc.)                                      | 2 h                                         | Indefinite until evaluated                         |                                | x       | Prevention of loss of material stored<br>Lower insurance rates                                                                                                                                                                                       |
| 3.8     | Production    | Critical process power (sugar factory, steel mills, chemical processes, glass products, etc.) | 1 min                                       | To return to prime power or until orderly shutdown |                                | x       | Prevention of product and equipment damage<br>Continued normal production<br>Reduction of payment to workers on guaranteed wages during nonproductive period<br>Lower insurance rates<br>Prevention of prolonged shutdown due to nonorderly shutdown |

**Table 3-2—Condensed general criteria for preliminary consideration (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 |                                                                                                                                                                                                                   |
| 3.8<br>(Cont.) | Production<br>(Cont.) | Process control power                  | Uninterruptible to 1 min                    | To return to prime power                  | x                              | x       | Prevention of loss of machine and process computer control program<br>Maintaining production<br>Prevention of safety hazards from developing<br>Prevention of out-of-tolerance products                           |
| 3.9            | Space conditioning    | Temperature (critical application)     | 10 s                                        | 1 min To return to prime power            | x                              | x       | Prevention of personnel hazards<br>Prevention of product or property damage<br>Lower insurance rates<br>Continuation of normal activities<br>Prevention of loss of computer function                              |
|                |                       | Pressure (critical) pos/neg atmosphere | 1 min                                       | 1 min To return to prime power            | x                              | x       | Prevention of personnel hazards<br>Continuation of normal activities<br>Prevention of product or property damage<br>Lower insurance rates<br>Compliance with local, state, and federal codes, standards, and laws |

Table 3-2—Condensed general criteria for preliminary consideration (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<br>(Cont.) | Space conditioning<br>(Cont.) | Humidity<br>(critical)       | 1 min                                       | To return to prime power                      |                                | x       | Prevention of loss of computer functions<br>Maintenance of normal operations and tests<br>Prevention of explosions or other hazards                    |
|                |                               | Static charge                | 10 s or less                                | To return to prime power                      | x                              | x       | Prevention of static electric charge and associated hazards<br>Continuation of normal production (printing press operation, painting spray operations) |
|                |                               | Building heating and cooling | 30 min                                      | To return to prime power                      |                                | x       | Prevention of loss due to freezing<br>Maintenance of personnel efficiency<br>Continuation of normal activities                                         |
|                |                               | Ventilation<br>(toxic fumes) | 15 s                                        | To return to prime power or orderly shut-down | x                              | x       | Reduction of health hazards<br>Compliance with local, state, and federal codes, standards, and laws<br>Reduction of pollution                          |

**Table 3-2—Condensed general criteria for preliminary consideration (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<br>(Cont.) | Space conditioning<br>(Cont.) | Ventilation<br>(explosive atmosphere)       | 10 s                                        | To return to prime power or orderly shutdown                    | x                              | x       | Reduction of explosion hazard<br>Prevention of property damage<br>Lower insurance rates<br>Compliance with local, state, and federal codes, standards, and laws<br>Lower hazard of fire<br>Reduce hazards to personnel                                                                                                                  |
|                |                               | Ventilation<br>(building general)           | 1 min                                       | To return to prime power                                        |                                | x       | Maintaining of personnel efficiency<br>Providing make-up air in building                                                                                                                                                                                                                                                                |
|                |                               | Ventilation<br>(special equipment)          | 15 s                                        | To return to prime power or orderly shutdown                    | x                              | x       | Purging operation to provide safe shutdown or startup<br>Lowering of hazards to personnel and property<br>Meeting requirements of insurance company<br>Compliance with local, state, and federal codes, standards, and laws<br>Compliance with local, state, and federal codes, standards, and laws<br>Continuation of normal operation |
|                |                               | Ventilation<br>(all categories noncritical) | 1 min                                       | Optional                                                        |                                | x       | Maintaining comfort<br>Preventing loss of tests                                                                                                                                                                                                                                                                                         |
|                |                               | Air pollution control                       | 1 min                                       | Indefinite until evaluated; compliance or shutdowns are options | x                              | x       | Continuation of normal operation<br>Compliance with local, state, and federal codes, standards, and laws                                                                                                                                                                                                                                |

Table 3-2—Condensed general criteria for preliminary consideration (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 |                                                                                                                                                     |
| 3.10    | Fire protection | Annunciator alarms                        | 1 s                                         | To return to prime power                     | x                              |         | Compliance with local, state, and federal codes, standards, and laws<br>Lower insurance rates<br>Minimizing life and property damage                |
|         |                 | Fire pumps                                | 10 s                                        | To return to prime power                     |                                | x       | Compliance with local, state, and federal codes, standards, and laws<br>Lower insurance rates<br>Minimizing life and property damage                |
|         |                 | Auxiliary lighting                        | 10 s                                        | 5 min To return to prime power               | x                              | x       | Servicing of fire pump engine should it fail to start<br>Providing visual guidance for fire-fighting personnel                                      |
| 3.11    | Data processing | CPU memory tape/disk storage, peripherals | 1/2 cycle                                   | To return to prime power or orderly shutdown | x                              | x       | Prevention of program loss<br>Maintaining normal operations for payroll, process control, machine control, warehousing, reservations, etc.          |
|         |                 | Humidity and temperature control          | 5–15 min (1 min for water-cooled equipment) | To return to prime power or orderly shutdown |                                | x       | Maintenance of conditions to prevent malfunctions in data processing system<br>Prevention of damage to equipment<br>Continuation of normal activity |

**Table 3-2—Condensed general criteria for preliminary consideration (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 |                                                                                                                                                                                      |
| 3.12    | Life support and life safety systems (medical field, hospitals, clinics, etc.) | X-ray                                  | Milliseconds to several hours               | From no requirement To return to prime power, as evaluated | x                              | x       | Maintenance of exposure quality<br>Availability for emergencies                                                                                                                      |
|         |                                                                                | Light                                  | Milliseconds to several hours               | To return to prime power                                   | x                              | x       | Compliance with local, state, and federal codes, standards, and laws<br>Preventing interruption to operation and operating needs                                                     |
|         |                                                                                | Critical-to-life machines and services | 1/2 cycle to 10 s                           | To return to prime power                                   | x                              | x       | Maintenance of life<br>Prevention of interruption of treatment or surgery<br>Continuation of normal activity<br>Compliance with local, state, and federal codes, standards, and laws |
|         |                                                                                | Refrigeration                          | 5 min                                       | To return to prime power                                   |                                | x       | Maintaining blood, plasma, and related stored material at recommended temperature and in prime condition                                                                             |

Table 3-2—Condensed general criteria for preliminary consideration (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 |                                                                                                                                                                                    |
| 3.13    | Communication systems | Teletypewriter                             | 5 min                                       | To return to prime power                  |                                | x       | Maintenance of customer services<br>Maintenance of production control and warehousing<br>Continuation of normal communication to prevent economic loss                             |
|         |                       | Inner building                             | 10 s                                        | To return to prime power                  | x                              |         | Continuation of normal activity and control                                                                                                                                        |
|         |                       | Television (closed circuit and commercial) | 10 s                                        | To return to prime power                  |                                | x       | Continuation of sales<br>Meeting of contracts<br>Maintenance of security<br>Continuation of production                                                                             |
|         |                       | Radio systems                              | 10 s                                        | To return to prime power                  | x                              | x       | Maintenance of security and fire alarms<br>Providing evacuation instructions<br>Continuation of service to customers<br>Prevention of economic loss<br>Directing vehicles normally |
|         |                       | Intercommunications systems                | 10 s                                        | To return to prime power                  | x                              | x       | Providing evacuation instructions<br>Directing activities during emergency<br>Providing for continuation of normal activities<br>Maintaining security                              |
|         |                       | Paging systems                             | 10 s                                        | 1/2 h                                     | x                              | x       | Locating of responsible persons concerned with power outage<br>Providing evacuation instructions<br>Prevention of panic                                                            |
|         |                       |                                            |                                             |                                           |                                |         |                                                                                                                                                                                    |

**Table 3-2—Condensed general criteria for preliminary consideration (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 |                                                                                                                                                                                                                                                                                                            |
| 3.14    | Signal circuits | Alarms and annunciation                                 | 1–10 s                                      | To return to prime power                  | x                              | x       | Prevention of loss from theft, arson, or riot<br>Maintaining security systems<br>Compliance with codes, standards, and laws<br>Lower insurance rates<br>Alarm for critical out-of-tolerance temperature, pressure, water level, and other hazardous or dangerous conditions<br>Prevention of economic loss |
|         |                 | Land-based aircraft, railroad, and ship warning systems | 1 s to 1 min                                | To return to prime power                  | x                              | x       | Compliance with local, state, and federal codes, standards, and laws<br>Prevention of personnel injury<br>Prevention of property and economic loss                                                                                                                                                         |

Readers using this recommended practice 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 in 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 should 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 101-1994) emergency systems are installed, lighting must be maintained for at least 1.5 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 for 10–12 h for every 24 h the normal power source is off. For this reason, the unit battery equipment is not recommended for auxiliary perimeter lighting.

### **3.2.4 Warning lights**

Emergency power should be available for all warning lights such as aircraft warning lights on high structures, ship warning lights on edges of waterways, and other warning lights that act to prevent injury or property damage. The power source selected should be capable of supplying emergency power throughout the duration of the longest anticipated power failure; therefore, the unit battery type is normally not suited for this application.

### 3.2.5 Health care facilities

Emergency lighting is of paramount importance in hospitals and similar institutions. The requirements for these areas are included in 3.12.

### 3.2.6 Standby lighting for equipment repair

Standby power for lighting should be installed in areas where the most probable internal power system failures may occur and in the main switchgear rooms. This requirement is justified by the necessity of having enough light to repair the equipment that failed and caused the loss of normal lighting.

### 3.2.7 Lighting for production

Interruption of power to a normal lighting system may cause serious curtailment or complete loss of production. Where there are no safety hazards or property damage associated with this need, the decision should be based on the economic evaluation of each particular application. Systems that provide power for emergency lighting may also provide high-level lighting to allow production to continue.

### 3.2.8 Lighting to reduce hazards to machine operators

A machine operator may be subjected to a high injury risk for the first few seconds after lighting has failed. Many machines present a safety hazard if suddenly plunged into darkness. Instantaneous emergency lighting is required for protection against this type of injury.

### 3.2.9 Supplemental lighting for high-voltage discharge systems

If mercury or other types of high-voltage discharge lighting are used for the regular system, consideration should be given to adding auxiliary lamps, such as incandescent or fluorescent. Some high-voltage discharge lamps require a cooling period before they restrike the arc and a warm-up period before they attain full brilliance. The total time required for full illumination after a momentary power interruption can range from 1 min for high-pressure sodium to 20 min for metal halide and mercury vapor.

### 3.2.10 Codes, rules, and regulations

Many states and municipalities have adopted their own specific codes regarding emergency lighting, in addition to those set down by the following organizations:

- The Occupational Safety and Health Act of 1970 (OSH Act) is charged with enforcing compliance and makes reference to the NEC and NFPA codes.
- NFPA 70-1996, the National Electric Code (NEC), Article 700, sets forth the standard of practice for emergency lighting equipment with regard to installation, operation, and maintenance.

- ANSI/NFPA 101-1994, the Life Safety Code, concerns itself with the specification of locations where emergency lighting is considered essential to life safety and specifics on exit marking.
- Underwriter's Laboratories, Inc., tests and approves equipment to uniform performance standards as established by ANSI/UL 924-1990.

### 3.2.11 Recommended systems

For short durations, primarily for personnel safety and evacuation purposes, battery units are satisfactory. For applications requiring longer service and heavier loads, an engine- or turbine-driven generator, which starts automatically upon failure of the prime power source, may be more suitable. ANSI/NFPA 101-1994 requires that emergency lighting facilities provide no less than an average of 10 lx ((1 fc) measured at any point along the path of egress at floor level. The standard allows illumination to decline to 6 lx (0.6 fc) average and 0.6 lx (.06 fc) minimum at the end of 1-1/2 h. The maximum to minimum illumination level may not exceed a ratio 40/1.

Table 3-3 summarizes the user's needs for emergency and standby electric power for lighting by application and areas.

## 3.3 Startup power

### 3.3.1 Introduction

Assume a cold boiler and a dead plant without electrical power or steam. From this premise, several very important issues must be considered:

- How will the plant be protected from freezing in cold weather? Even with gas heaters, will there be sufficient heat without fans and without interlocked make-up air units running?
- A steam turbine generator is on hand, but without forced draft, induced draft, boiler feed water, flame detectors, or control power. How can it be started?
- A gas turbine generator has been installed, but how can this be started without bringing it up in speed with a small steam turbine, an electric motor, or other prime mover? Gas compressors may be necessary and also require prime movers of some type.
- Steam-driven and electrically driven fire pumps are out of service. There may be no major fire protection until electric power or steam is restored.
- An uninterruptible power supply (UPS) of sufficient capacity is probably not on hand; otherwise, steam and electric power would not be down.

These statements illustrate the fact that adequate startup power is one of the most important considerations in the original design of any plant. Millions of dollars worth of equipment could be standing idle at a time of critical need if no allowance were made for starting the machines under expected conditions, such as a major power outage.

**Table 3-3—Typical emergency and standby lighting recommendations**

| Standby <sup>a</sup>                                                                                               | Immediate, short-term <sup>b</sup>                                                               | Immediate, long-term <sup>c</sup>                                                                                |
|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| Security lighting<br>Outdoor perimeters<br>Closed circuit TV<br>Night lights<br>Guard stations<br>Entrance gates   | Evacuation lighting<br>Exit signs<br>Exit lights<br>Stairwells<br>Open areas<br>Tunnels<br>Halls | Hazardous areas<br>Laboratories<br>Warning lights<br>Storage areas<br>Process areas                              |
| Production lighting<br>Machine areas<br>Raw materials storage<br>Packaging<br>Inspection<br>Warehousing<br>Offices | Miscellaneous<br>Standby generator areas<br>Hazardous machines                                   | Warning lights<br>Beacons<br>Hazardous areas<br>Traffic signals                                                  |
| Commercial lighting<br>Displays<br>Product shelves<br>Sales counters<br>Offices                                    |                                                                                                  | Health care facilities<br>Operating rooms<br>Delivery rooms<br>Intensive care areas<br>Emergency treatment areas |
| Miscellaneous<br>Switchgear rooms<br>Landscape lighting<br>Boiler rooms<br>Computer rooms                          |                                                                                                  | Miscellaneous<br>Switchgear rooms<br>Elevator<br>Boiler rooms<br>Control rooms                                   |

<sup>a</sup> An example of a standby lighting system is an engine-driven generator.

<sup>b</sup> An example of an immediate short-term lighting system is the common unit battery equipment.

<sup>c</sup> An example of an immediate long-term lighting system is a central battery bank rated to handle the required lighting load only until a standby engine-driven generator is placed on-line.

### 3.3.2 Example of a system utilizing startup power

Starting major plant equipment without outside power is commonly referred to as a *black start* and is accomplished by using only the facilities available within the plant. One example of a system designed with black start capability, with a minimum electrical startup system, would be a large gas turbine driving a centrifugal compressor in the natural gas pipeline industry, where the high-pressure gas from the pipeline is used to drive expansion turbines and gas motors for cranking the turbine, operating pumps, and positioning valves. By utilizing the high-pressure gas for the large horsepower requirements, a small engine-driven generator, fueled by natural gas, is used to provide electric power for turbine accessories, battery charging, lighting, and powering other critical loads. When the turbine is running, a shaft-driven generator provides larger quantities of electric power for all station requirements; the small generator is placed on *standby*.

### 3.3.3 Lighting

In the design of the startup power system, first consideration should be given to installing battery-operated lights in the vicinity of the standby power source and switchgear.

### 3.3.4 Engine-driven generators

The battery-cranking power for the engine may also be used for some lights. Cranking may also be accomplished by compressed air supplied to a tank by the plant compressed-air system and prevented from leaving the tank into the plant system by a check valve.

The engines may be sized for short-term operation if some type of continuous power generation can be brought onto the line after startup. If no generation as a prime source of electric power has been installed, the diesel or engine generator should be sized for supporting all electrical needs for the generator auxiliaries, boilers, critical emergency lights, fire signals, exit lights, and other items listed in table 3-2.

### 3.3.5 Battery systems

Special consideration should be given to the design of the plant battery system or UPS, allowing for (1) adequate battery capacity to provide power for the necessary startup control systems, following a programmed safe stop; and (2), when possible, special disconnecting devices to automatically disconnect large power-consuming systems from the battery system to conserve battery capacity for restart.

With capacity for these minimum facilities in operation, consideration may then be given to installing sufficient capacity at the same time to support additional justified needs.

### 3.3.6 Other systems

Mobile equipment may suffice if it can reasonably be assumed to be available when needed. (Who has the highest priority when all have the need?) An alternate standby public utility line may also be available at a low cost from a separate source of supply. A neighboring plant with live generation may assist in an emergency.

### 3.3.7 System justification

A definite workable plan with the proper equipment should be evaluated, and action taken as justified, prior to the need.

## 3.4 Transportation

### 3.4.1 Introduction

This topic covers the moving of people and products by methods that depend upon electric power. The importance of maintaining power for these methods ranges from desirable to critical.

### 3.4.2 Elevators

Where two or more elevators are in use in buildings three or more stories high, the elevators or banks of elevators should be connected to separate sources of power. There are situations where standby power is required for all elevators within 15 s. Savings may be made by supplying power during outages of the normal supply to one-half the elevators installed, providing the traffic can be rerouted and the capacity of the elevators is adequate. Power must be transferred to the second bank of elevators within 1 min or so of the prime power loss to clear stalled elevators. Power may be left on this bank until normal power returns.

Where elevator service is critical for personnel and patients, it is desirable to have automatic power transfer with manual supervision. Operators and maintenance men may not be available in time, if the power failure occurs on a weekend or at night.

Where a single feeder supplies more than one elevator, selective coordination of the protective devices may enhance elevator availability. This is a requirement of the 1996 edition of the NEC, Section 620-26.

- *Typical elevator system.* Figure 3-3 shows an elevator emergency power transfer system whereby one preferred elevator is fed from a vital load bus through an emergency riser, while the rest of the elevators are fed from the normal service. By providing an automatic transfer switch for each elevator and a remote selector station, it is possible to select individual elevators, thus permitting complete evacuation in the event of power failure. The engine generator set and emergency riser need only be sized for one elevator, thus minimizing the installation cost. The controls for the remote selector, automatic transfer switches, and engine starting are independent of the elevator controls, thereby simplifying installation.
- *Regenerated power.* Regenerated power is a concern for motor generator-type elevator applications. In some elevator applications, the motor is used as a brake when the elevator is descending and generates electricity. Electric power is then pumped back into the power source. If the source is commercial utility power, it can easily be absorbed. If the power source is an engine-driven generator, the regenerated power can cause the generating set and the elevator to overspeed. To prevent overspeeding of the elevator, the maximum amount of power that can be pumped back into the generating set must be known. The permissible amount of absorption is approximately 20% of the generating set's rating in kilowatts. If the amount pumped back is greater than 20%, other loads must be connected to the generating set, such as emergency lights or "dummy" load resistances. Emergency lighting should be permanently connected to the generating set for maximum safety. A dummy load can also be automatically switched on the line whenever the elevator is operating from an engine-driven generator.

### 3.4.3 Conveyors and escalators

Escalators and personnel conveyors may require emergency power since physically handicapped persons ride up and would have great difficulty walking down, even though a normal person would be able to do so were the power off.

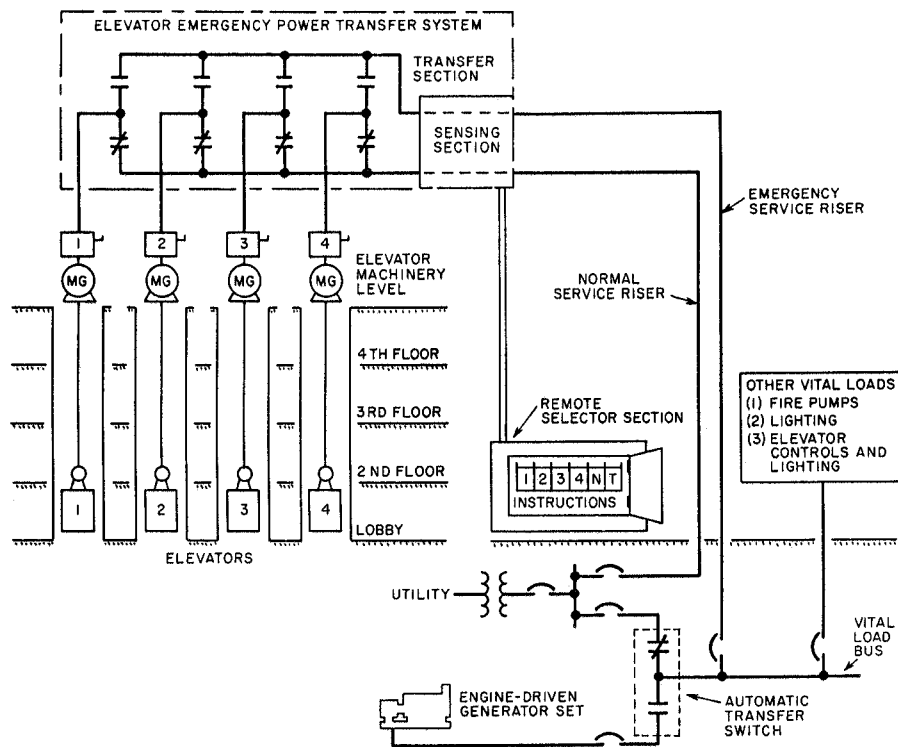


**Figure 3-3—Elevator emergency power transfer system**

Expanding systems require reevaluation of standby power needs each time equipment is added. Using conveyors to feed a few cattle or gather a few eggs may have once eased someone's labor, with labor filling in if needed. However, as these operations have become larger and larger, they have become more and more dependent upon electric power; therefore, the feasibility of electric power outage producing a disaster has increased, and the need for standby power more important.

### 3.4.4 Other transportation systems

Power for charging equipment for battery-powered vehicles is usually a noncritical requirement. Time available for the generation to come on-line varies from several minutes to several hours.

A few examples of transportation systems that may need standby power are the following:

- Conveyors for raw materials through to finished goods
- Warehouse high-stacking loading and unloading equipment, and conveyors delivering finished goods to shipping facilities
- Slurry pumps for long pipelines
- Livestock feeder conveyors

## 3.5 Mechanical utility systems

### 3.5.1 Introduction

Often the need for mechanical utilities is as great as that for electric power utilities. These are interdependent. We can speak of utility systems as a whole since, to most managers and corporate officials, these are all united in a group under the heading “utilities.”

### 3.5.2 Typical utility systems for which reliable power may be necessary

Mechanical utility systems comprise the following services for which reliable electric power is usually required:

- Compressed air for pneumatic power
- Cooling water (including return pumps, pressure pumps, tower fans)
- Well water or other pumped sources for personnel use
- Hydraulic systems
- Sewer systems (sanitary, industrial, storm)
- Gas systems (natural, propane, oxygen), including compressors
- Fire pumps and associated water supplies
- Steam systems (low and high pressures)
- Ventilation (building and process)
- Vacuum systems
- Compressed air for instrumentation

Although this list is not exhaustive, it alerts a plant manager or engineer to the various needs and potential losses that may occur if electric power is not available.

Systems may be required for manufacturing and services to maintain other services. For example, electric power, water, and compressed air for boilers used to supply steam for the generation of electricity.

A 0.1–5 s power failure may cause plant operators to spend minutes or hours restarting equipment and making adjustments until all systems are again stable. Such disruptions to production should be prevented if economically justifiable.

### 3.5.3 Orderly shutdown of mechanical utility systems

An orderly shutdown of power to mechanical utility systems may be acceptable with a short-time smaller supply source of power provided for the following requirements:

- Maintaining temperature or pressure on vulcanizers until the product can be finished.
- Maintaining hydraulic pressure until a batch process is completed, or until the pressure can be released without loss.
- Operating pumps for a time until all process water has been shut off or has drained back into the sumps to prevent flooding. This becomes serious when the water is con-

taminated with oil and other waste when flooding occurs and special handling may be needed to comply with antipollution requirements.

- Maintaining ventilation to clear explosive atmospheres while a normal shutdown proceeds. Purging air is critical to some oven-drying processes.
- Preventing sanitary sewers from overflowing before personnel evacuation takes place.
- Running gas compressors for the finishing of a critical process.

This list is not exhaustive, but represents needs of various types, which should be sufficient to alert a plant engineer so that a plan may be prepared for an orderly shutdown. Management may then be justified to act on the plan and not be caught unprepared in an emergency situation.

### 3.5.4 Alternates to orderly shutdown

An orderly shutdown may not be acceptable. Then an alternate may be selected, such as the following:

- *Maintaining utilities without an interruption.* Full capacity standby power must be available as well as uninterruptible power for boiler controls, on-line computers, and essential relays and motor starters.
- *Accepting an outage but returning on standby power.* Full capacity power must be available. Startup of functions will be required since magnetic motor starters and relays will have dropped out. Although power is off for 0.1–5 s, it will take 15–30 min or more for return to normal operation.

## 3.6 Heating

### 3.6.1 Maintaining steam production

Continuous-process plants require uninterrupted steam production. Minimum requirements for continuous steam production are sufficient combustion air, air to instruments and actuators, water and fuel supplies, plus a continuous power supply to most flame supervision systems. The maximum interruption tolerable is that duration during which the inertia of the fans or pumping equipment will maintain flows and pressures above minimum limits. Table 3-4 illustrates how this can be achieved.

### 3.6.2 Process heating

Process heating is defined as heat required to maintain certain process materials at the required temperature. Noncritical heating processes, due to the inherent heat capacities of such systems, can withstand a power interruption of considerable duration, i.e., 5 min to a maximum of several hours.

**Table 3-4—Systems for continued steam production**

| Components                         | Allowable outage duration                                                                             | Systems                                                                                                                                                       |
|------------------------------------|-------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Flame supervision systems          | Nil                                                                                                   | Mechanical stored energy systems<br>Motor-generator set ride-through<br>UPS systems                                                                           |
| Motor controls and instrumentation | Nil                                                                                                   | Same as above                                                                                                                                                 |
| Boiler fans                        | 1/2 to 2 s                                                                                            | Multiple utility services, either on-line and relayed, or off-line, switched, and transferred                                                                 |
| Air compressor                     | To 30 min, depending on storage; nonessential air users should be automatically shut off              | Multiple utility services<br>Turbine- or engine-driven generator, off-line<br>Turbine (combustion, steam, water), off-line                                    |
| Water pump                         | To 5 min, depending on water drum capacity and upsets in steam production caused by power disturbance | Multiple utility services either on-line and relayed, or off-line, switched, and transferred<br>Turbine (combustion, steam, water), off-line, automatic start |
| Oil pumps (for burners)            | To 15 cycles, more with flywheel                                                                      | Multiple utility services, on-line and relayed<br>Turbine (combustion, steam, water), on-line                                                                 |
| Electric oil supply pumps          | Several minutes                                                                                       | Turbine- or engine-driven generator, off-line<br>Multiple utility services, on- or off-line                                                                   |

Any of the following systems would be adequate for this application:

- Engine-driven generators, off-line
- Multiple utility services, on-line and relayed, or off-line, switches, and transfers
- Turbine (combustion, steam, water), off-line or on-line
- Mechanical stored-energy system, with auxiliary motor generator sets off-line

Other heating processes, such as cord and fabric treating and drying, are of such a critical nature that loss of heat will cause an out-of-specification product within 10 s, but the gas or oil burners and flame detectors are sensitive to drops in voltage of about 40% for a second or less. In this case, an uninterruptible supply for the controls and an engine generator for a 10 s main power supply or an alternate feed system may be required.

Infrared drying of enamel on automobiles and appliances is a form of heating by electric energy that must be maintained. A short interruption, perhaps 10 s, may be acceptable to bring on-line standby generation or perform automatic switching to an auxiliary power source.

Losses may be substantial if power is lost during the heat treating of metals and when either direct or indirect melting of metals is in process. Two evaluations must be made: one based on not losing the flame on the fuels used, and the other based on accepting an interruption for a short period with a restart necessary. Uninterruptible power is several times more expensive than switching or emergency power, but saves the product and prevents process interruption. Switching or emergency power is less expensive, but product or process losses may exceed the initial savings in the chosen electric supply system.

Induction and dielectric heating are other forms of electrical heating that may or may not allow short interruptions to be tolerated. Most processes, whether in production or in other fields, could tolerate an interruption of sufficient duration to come on-line with switched sources or an engine- or turbine-driven generator.

### 3.6.3 Building heating

Buildings, even in the coldest regions, can usually be without heating for a minimum of 30 min. The same systems listed for noncritical heating processes will be suitable for this application.

## 3.7 Refrigeration

### 3.7.1 Requirements of selected refrigeration applications

Requirements for refrigeration are usually noncritical for short power interruptions of several minutes to several hours. The need may become extremely critical as the length of time of the outage increases. Consider these refrigeration needs:

- Production of ice cream or the freezing of foods may stop in the middle of the process. Not only will all production be lost during a power failure, but damage may result to the product in process.
- Material in storage may be in jeopardy as temperatures rise. Cafeterias, frozen food lockers, meat cooling and storage facilities, dairies, and other food operations require refrigeration and will soon be in trouble as the length of the power outage increases.
- Scientific tests of long duration may require accurately maintained low temperatures. Short outages of electric power may destroy the tests and require repeating. An

expensive and time-consuming process should be provided with a standby power system.

- Medical facilities require refrigeration for blood banks, antibiotics, and for long-range laboratory experiments and cultures that could be spoiled.
- As the state of the art of superconductivity develops, improves, and spreads to applicable fields, power for cryogenic refrigeration equipment operation will probably become critical.

Where present refrigeration units are electrically driven, when new units of moderate size are to be installed in permanent locations, and when other needs exist (as is usually the case) for emergency or standby power, a common engine-driven generator or alternate utility source should be considered.

Because of the slow rise in temperature of cold-storage facilities, a savings may be made by the use of a smaller than normal standby electric generator. By switching power to various units in turn, an acceptable storage temperature may be maintained until normal electric power has been reestablished.

### **3.7.2 Refrigeration to reduce hazards**

Certain chemical processes are exothermal and release heat during the chemical reaction. Loss of the cooling or refrigeration system may cause severe damage or even an explosion.

### **3.7.3 Typical system to maintain refrigeration**

A manual starting of an engine-driven generator, turbine, or alternate utility supply will usually suffice, providing a suitable alarm is installed to notify responsible persons of a loss of refrigeration.

## **3.8 Production**

### **3.8.1 Justification for maintaining production in an industrial facility during a power failure**

Production continuation in an industrial facility during a power failure is justified by the total sum of many tangible and intangible savings. The following paragraphs discuss various considerations that can affect these savings.

Is there a guaranteed wage clause in the labor contract? If so, there will be a direct loss in wages paid for which no production is received. Where power requirements are low and the heavy-power-demanding machines are left shut down until normal power is returned, a small electric supply system can be justified to supply finishing areas, inspection areas, office areas, and other areas where most employees work.

Who is waiting for the product? There are periods when the products are being routed to warehouses and machines are not running at capacity previous to the outage. In this case, the