CHAPTER

6

POWER SOURCES

This chapter describes various types of power systems that are used for communications sites. It also specifies requirements for various types of power systems that are typically used at a communication site. The following topics are included:

6.1 LOCKOUT/TAGOUT

On all power systems (AC or DC), a provision **shall** be present to lock out and tagout any circuit to help ensure the circuit is safe to work on. (See NFPA 70-2005 for additional information.)

6.2 AC POWER

All AC power systems **shall** be designed, installed and maintained in accordance with jurisdictional standards and regulations.

All site power loading **shall** be determined for initial equipment installation and future expansion. The determined loads at various locations throughout the site **shall** then be factored into the site electrical design.

Continuous load **shall not** exceed 80% of the electrical system, (wire, panel board, breakers, and service rating). Using this standard allows all participants in site design (electric power company, prefabricated shelter vendor, UPS vendor, generator vendor, etc.) to ensure that the power capacity supplied to the communications site is adequate.

Minimum acceptable service for US installations is typically 100 amps @ 120/240 VAC (or 120/208 VAC). A 200 amp (or larger) service may be required for existing/future loads or for additional circuit breaker positions. (Other service parameters may be applicable for nondomestic installations.)

Sizing of AC power loads is critical in calculating supply capacity. Typical power needs are:

- HVAC system (including redundant units). Most sites consisting of shelters will not be continuously occupied. In such case, the service personnel heat load need not be considered.
- Room lights and possible outdoor security lighting

NOTE: A standby generator may be required for continuity of service at sites where tower lighting is required to meet FAA requirements.

- Tower lighting. Some tower lighting systems may require additional power capacity (strobes, multiple fixtures, etc.).
- Number of dedicated circuits for major pieces of equipment, including isolated equipment
- Battery chargers
- Uninterruptible power supplies (UPSs)
- Equipment powered by rectifier systems (-48 VDC or similar)
- Utility receptacles. The number of utility receptacles required at a site is determined based on the size of the equipment room or shelter.
- The AC electrical power requirements of the communications room when all transmitters are simultaneously keyed **shall** be considered (see NFPA 70-2005, Article 220 and Article 310.15 for additional information).
- Planned future expansion
- Consideration of unusual maximum continuous loads (such as trunked system failsoft operation).

6.2.1 ELECTRICAL SERVICE

The power company usually provides the service to the meter in underground installations and to the weatherhead in overhead installations. All wiring after the meter typically is the responsibility of the customer. Primary metering (high voltage) may be an exception. It is important to note the demarcation point used by the power company serving the region where the site is being constructed. This location affects installation costs.

The following requirements **shall** be observed when specifying and installing electrical service to the site building:

- Work practices that help ensure safety **shall** be observed while performing all electrical work as required by (but not limited to) agencies such as OSHA, NFPA, NFPA70-2005, BOCA and local codes.
- Throughout the US, the local buried utility locator service **shall** be contacted before excavating. In other countries, the local utility **shall** be consulted to obtain buried utility location service.

WARNING

Failure to properly locate buried utilities can pose hazards to personnel. Failure to comply with regulations regarding buried utilities can result in penalties.

- Electrical installation work **shall** be carried out in accordance with the current edition of the NFPA 70-2005 and local building codes. Where required, only a qualified and licensed electrician **shall** be used for all electrical installations.
- Underground and above ground service entrance conductors **shall** be protected from physical damage (see NFPA 70-2005, Article 230.50 and 300.5 for additional information).
- The service entrance conductor may be a material other than copper if permitted by local codes.

- The site electric meter **shall** be located where it is visible and accessible to power company meter readers and **shall** comply with all applicable codes and/or power company requirements.
- Meter access by power company personnel should be considered when determining meter location (especially where a fence is involved). (See NFPA 70-2005, Article 100 and Article 230 for details regarding locations and service conductors.)

NOTE: The following refers to the Main Disconnect for the separately derived system feeding the equipment room. The Main Disconnect may not be located in the same building as the equipment (a meter farm at a tower site, for example). This makes the panel in the building with the equipment a sub-panel and not the main disconnect.

- At all sites, there is either or both a main service disconnect and a fused disconnect. A main service disconnect may be located at a meter location away from the building. A main disconnect located within the shelter, equipment room or area may be fed by a feeder circuit originating at a main service disconnect located in an electrical room in a different location in the building or even a separate building. Typically, the neutral and ground conductors are bonded in the main service disconnect. When the main service disconnect is located remotely from the equipment room or area, a separately derived system should be installed in the equipment room. (See NFPA 70-2005, Article 250.30 and 250.32 for additional information.)

  One of the reasons for the separately derived system is to reestablish the neutral/ground bond, thereby improving the effectiveness of normal mode suppression.

NOTE: See Table 7-1 on page 7-7 and associated Chapter 7 figures for additional information regarding connections for separately derived systems.

- A fused disconnect **shall** always be installed before all other panels and equipment, including a generator transfer switch. (See NFPA 70-2005, Article 445.18 for additional information.)
- For a stand-alone equipment shelter, the main disconnect **shall** be located on the same wall as the coaxial cable entry port, the telephone entry point, and the MGB. If it is not possible to locate these components on the same wall, then these components **shall** be located on an adjacent wall as close together as possible. (See IEEE 1100-1999 Section 8.3.2.1.2 for additional information.)
- The main bonding jumper **shall** be installed between the neutral bus and the ground bus within the main service disconnect. This is to ensure an effective low-impedance neutral-to-ground bond connection. (See NFPA 70-2005, Article 250.24(B) for additional information.)
- Self-tapping or sheet metal type screws **shall not** be used for attaching ground or grounding conductors to any surface. (See NFPA 70-2005, Article 250.8 for additional information.)
- Paint, enamel, lacquer, or other nonconductive coatings **shall** be removed from threads and surface areas where connections are made. (See NFPA 70-2005, Article 250.12 for additional information.)

6.2.2 LOCATION OF NEUTRAL-GROUND BOND

It is strongly recommended for the proper performance of electronic equipment that the voltage between the neutral and ground conductors at the equipment be no more than 2V p-p (0.7 Vrms). Where the disconnecting means of the electrical service is remotely located to the site, the voltage developed between neutral and ground may cause equipment to malfunction, especially during a ground potential rise at the site. For the optimum performance of a Surge Protective Device (SPD) installed at the AC distribution panelboard, the Neutral-to-Ground bond must be near the SPD in order for the SPD to effectively redirect unwanted energies on the AC power cables safely to the site grounding (earthing) electrode system. Due to the physical separation between the remote service entry disconnecting means and the site disconnecting means, a steady state ground loop current could flow on the equipment grounding conductor bonding the two ground fields.

An approach for eliminating the steady state ground loop current and lowering the voltage between the Neutral and Ground conductors is to bond the Neutral-to-Ground at the remote service entry disconnecting means, and at the communications site disconnecting means as allowed by NFPA 70-2005, Article 250.32(B)(2). In order to accomplish this, the equipment-grounding conductor between the remote disconnecting means and the site disconnecting means **shall** be disconnected at both ends and removed.

Neutral-ground bonding requirements as allowed by NFPA 70-2005, Article 250.32 include:

- The AC equipment grounding (ACEG) conductor **shall not** be run between the remote disconnecting means and the shelter's disconnect.
- There **shall** be no other metallic continuity established between the remote disconnecting means and the site. Examples of continuity that is not permitted between the remote disconnecting means and the site could include metallic conduit and the data/ telecommunications metallic shields installed between the remote electrical service area and the site.
- Ground fault protection **shall not** be installed on the common AC service of the electrical disconnect

NFPA 70-2005, Article 250.32(B)(2) allows the bonding of the neutral and ground conductors at the separate building or structure and also eliminates the creation of parallel paths for normal neutral current on grounding conductors, metal raceways, metal piping, and other metal structures. In previous editions of the Code, the grounding electrode conductor and equipment-grounding conductors were permitted to be connected to the grounded conductor at a separate building or structure. This multiple-location grounding arrangement could provide parallel paths for neutral current along the equipment grounding conductors of the electrical system, metallic shields of cables, metallic structures that are continuous between, buildings, and along other continuous metallic piping and mechanical systems as well. Connection of the grounded conductor to a grounding electrode system at a separate building or structure is permitted only if these parallel paths are not created and if there is no common ground-fault protection of equipment provided at the service where the feeder or branch circuit originates. See Figure 6-1 on page 6-5.

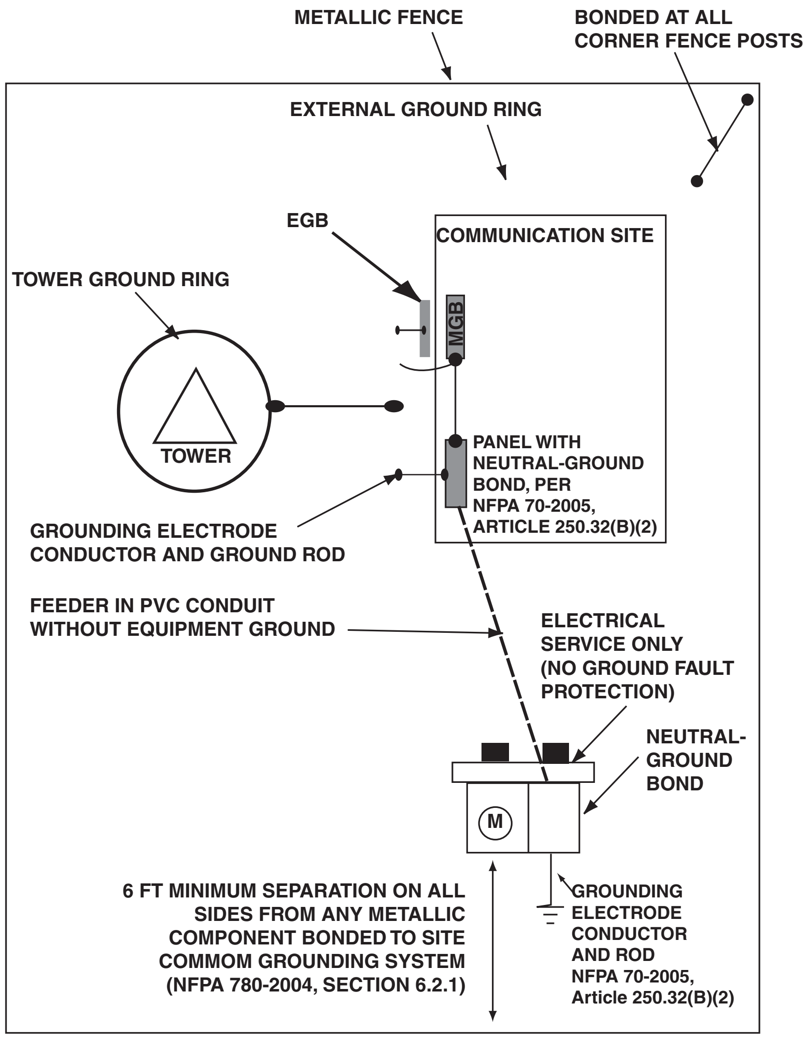


FIGURE 6-1 REESTABLISHING THE NEUTRAL-GROUND BOND AT THE COMMUNICATION SITE

6.2.3 SEPARATELY DERIVED SYSTEMS USING TRANSFORMERS

Communications site AC power can also be supplied by a transformer (also known as an isolation, step-down, or step-up transformer). Separately derived transformers are typically used to step down three-phase 277/480 VAC service to standard commercial 120/208 VAC service.

To improve the effectiveness of line-to-neutral (normal mode) surge suppression, the transformer creates a separately derived system where the neutral and ground conductors **shall** be bonded together within the transformer or within the first disconnect after the transformer and bonded to the building's common grounding electrode system. (see NFPA 70-2005, Article 250.30 for additional information.) See "Separately Derived AC Systems" on page 5-42.

6.2.4 INTERIOR ELECTRIC

The following requirements **shall** be observed when specifying and installing interior electrical service:

- All panel boards and switch boards **shall** display signage and placarding per NFPA 70-2005, Article 110.22 and applicable local codes.
- When designing a site floor plan with electrical panels utilizing voltages of 600 VAC or less, a clearance of 914 mm (36 in.) **shall** be provided in front of any electrical panel in accordance with NFPA 70-2005, Article 110.26.
- A working space equal to the width of the equipment or 762 mm (30 in.), whichever is greater, **shall** be provided in accordance with NFPA 70-2005, Article 110.26.
- Additional clearance **shall** be provided based on the voltage present in electrical panel exceeding 120/240 VAC. See Figure 6-2.

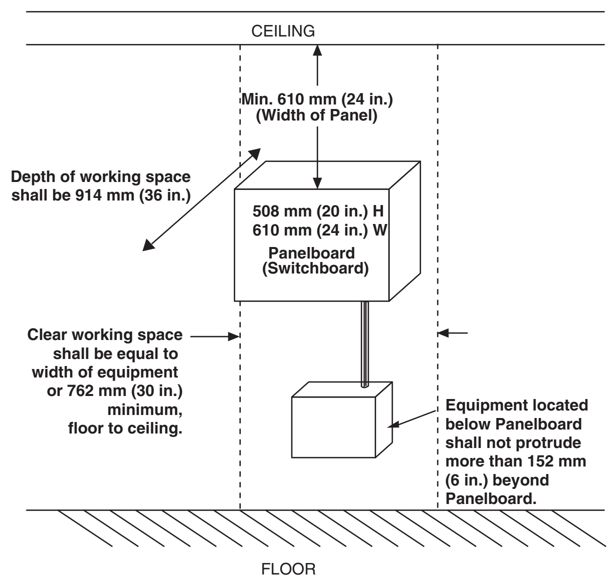


FIGURE 6-2 ELECTRICAL PANEL CLEARANCES

- Equipment that operates on 48 VDC, or 600 VAC require different clearance. Clearance **shall** be in accordance with NFPA 70-2005, Article 110.26, or applicable local codes.
- All internal wiring **shall** be copper. (see NFPA 70-2005, Article 110.5 for additional information).
- Power panels, load centers, and breaker boxes **shall** be identified using distinctive placarding/labeling identifying their purpose and location of the main service disconnect. (See NFPA 70-2005, Article 110.22 and Figure 8-3 for additional information.)
- Wire, terminals and lugs **shall** be of similar or compatible metals (NFPA 70-2005, Article 110.14).

6.2.5 POWER PANELS

The following requirements **shall** be observed when specifying and installing interior electrical service:

- Each main distribution panel **shall** have its own main overcurrent protective device (circuit breaker/fuse). (See NFPA 70-2005, Article 408.36(B) for additional information.)
- All interior panelboards and junction boxes **shall** be NEMA Type 1 general purpose for indoor application.
- More than one distribution panel may be necessary for large single equipment rooms in order to support the number of required branch circuits. If more than one distribution panel is utilized then all panels **should** be fed from the same separately derived system. This is done to prevent ground loops from multiple neutral ground bonds at the transformer. (See IEEE STD 1100-1999 for additional information.)
- Power panelboards **shall** be bonded to the interior single point grounding window system. See “Internal Grounding (Earthing)” on page 5-1 for the requirements on the proper methods of grounding and bonding equipment.
- When using a UPS, two distinct power panels **shall** be utilized as follows:
    - Equipment Power Panel (UPS Panelboard)

      This panel provides power for the communications equipment and all associated electrically powered items. It is fed from the UPS.
    - Utility Power Panel

      This panel provides power for circuits and loads other than the communications equipment. This panel feeds the UPS and non-UPS site electrical equipment such as lighting, HVAC and wall mounted receptacles, etc.

6.2.5.1 OUTDOOR ELECTRICAL (BRANCH CIRCUITS)

This paragraph provides requirements for branch circuits that exit the equipment shelter for use with outdoor equipment.

- All outdoor electrical equipment **shall** be protected from the environment and sealed from the elements.
- All outdoor receptacles **shall** be GFCI-type receptacles or breakers. (See NFPA 70-2005, Article 210.8 for additional information.)
- Non-flexible conduit **shall** be used for all exterior circuit branches. An exception are feeds to vibrating equipment such as air conditioning units, which may use liquid-tight flexible sealed conduit.
- All exterior wall penetrations through which conduit passes **shall** be sealed.
- Exterior panelboards, receptacles and switches **shall** be housed in NEMA Type 3 or Type 3R housing.

6.2.6 CIRCUIT PROTECTION

The following requirements **shall** be observed when specifying and installing circuit protection devices:

NOTE: Locked-rotor starting current **shall** be considered when specifying breaker values for such items as the air conditioner compressor motors and fans. Power amplifiers keyed to full power can also pose unusual start-up loads. Such loads may also affect the type of breaker used for the circuit.

- A means of removing power from a given circuit or load without disrupting other equipment **shall** be provided.
- Circuits for communication equipment **shall** be 15 A minimum. 20 A circuits are recommended for each branch circuit feeding communications equipment and associated equipment.
- Branch circuit breakers for all other equipment such as lighting, heating and air conditioning **shall** be rated per manufacturer specifications as per code.
- Breakers and their associated receptacles **shall** be uniquely labeled and correlated to the respective power panel unless required differently for specific equipment. (See NFPA 70-2005, Article 408.4 for additional information.)
- Panel schedule **shall** be filled out and kept up to date. (See NFPA 70-2005, Article 408.4 and Figure 6-3 for additional information).

FIGURE 6-3 PANEL SCHEDULE

- Circuit breakers **shall** be sized to protect the conductor attached to them, not the load on the circuit. (See NFPA 70-2005, Article 240.4 for additional information.)

6.2.7 CONDUCTORS

The following requirements **shall** be observed when specifying and installing conductors:

- Aluminum conductors **shall not** be used.
- All branch conductors **shall** have an allowable ampacity equal to or greater than the non-continuous load plus 125% of the continuous load. (See NFPA 70-2005, Article 210.19(A)(1) for additional information.)
- It is recommended that a conductor of 8 mm^2 csa (#12 AWG) minimum be used in the equipment panel for circuit branches.

NOTE: On 3-phase branch circuits it is very important that the neutral conductor be sized appropriately for overcurrent that may be induced upon the neutral by a possible load imbalance.

- The neutral conductor **shall** be equivalent in size to its associated load carrying conductors. In special circumstances (such as highly reactive loads that may generate harmonics), the neutral should be increased to up to 175% of its original size. (See NFPA 70-2005, Article 220.61 for additional information.)
- All single phase circuits **shall** be 3-wire.

6.2.8 CONDUIT

The following requirements **shall** be observed when specifying and installing conduit:

- All interior surface-mounted building wiring **shall** be run in rigid electrical metallic tubing (EMT) or electrical raceways. (See NFPA 70-2005, Article 358 and IEEE STD 1100-1999, *Powering and Grounding Electronic Equipment* paragraph 8.4.8.2. for additional information.
- The conduit **shall not** be used as the AC equipment grounding (ACEG) conductor. An individual circuit equipment grounding conductor **shall** be installed in each conduit exiting the panelboard and be connected electrically. The arrangement of grounding connections **shall** be such that the disconnection or removal of a receptacle, fixture, or other device fed from the box will not interfere with (or interrupt) the equipment grounding conductor continuity.
- The conduit **shall** be securely fastened every 3 m (10 ft.) and within 914 mm (3 ft.) of any receptacle box, junction box, panel board or any termination of the conduit. (See NFPA 70-2005, Article 358.30 for additional information.)
- For tenant improvements, applicable local codes **shall** be observed.
- Conduit runs may be mounted to the cable tray support structure. These cable trays (along with ceiling attachments) **shall** be designed and installed to support an EMT distribution system, including all hardware-related fittings and boxes, as well as the distributed load in the tray. (See NFPA 70-2005, Article 314.23 for additional information.)
- Conduit **shall not** be mounted to cable trays in isolated ground zones.
- Flexible metal conduit may be used to carry a circuit branch conductor to vibrating equipment, and suspended lighting fixtures. (See NFPA 70-2005, Article 348 for additional information.)
- Liquid-tight flexible metal conduit **shall** be used where additional protection from liquids, vapors or solids is required. (See NFPA 70-2005, Article 350 for additional information.)

6.2.9 HARDWIRING OF EQUIPMENT AND DEDICATED RECEPTACLES

Extension cords **shall not** be used to power permanent communication equipment at a site.

When an open equipment rack is used, hardwiring of power is not always possible. Mounting a dedicated simplex receptacle or receptacle assembly on the rack may be the most convenient method of supplying power, especially if multiple pieces of equipment are mounted on the rack. This is also a convenient way to install personal protection Type 3 SPD devices to the equipment.

These receptacle assemblies can be pre-manufactured and mounted to the top face of an equipment rack. Mounting can also use a fabricated power pole mounted between racks.

6.2.10 RECEPTACLES

The following requirements **shall** be observed when specifying and installing receptacles for powering communications equipment:

- To ensure reliability, each major piece of equipment and each half of a redundant power supply **shall** have its own dedicated individual branch circuit and dedicated simplex receptacle.
- Equipment racks may require special attention to support the dedicated simplex receptacle scheme. To comply with the dedicated simplex receptacle concept, receptacles have to be located on or very near the rack of equipment. One method is to use a specialized Multi-Receptacle AC panel with dedicated circuits that **shall** be mounted on the equipment rack or enclosure. (These Multi-Receptacle AC panels **shall** be hard wired to the breaker panel, and each simplex receptacle **shall** use an individual branch circuit.)
- To eliminate the possibility of two pieces of equipment turning on at the same time and momentarily exceeding the amperage capacity of the circuit, simplex receptacles should be used instead of duplex receptacles.

NOTE: Duplex receptacles may be fed from two separate circuits only if the connecting tabs on the receptacles are removed. The neutral **shall not** be shared by two receptacles. In this case, only one equipment grounding conductor is required for the two circuits.

- Receptacle ratings should be determined by conductor and circuit breaker current ratings. Consider future expansions.
- Isolated ground receptacles should not be used unless recommended by the equipment manufacturer (IEEE STD 1100-1999). Isolated ground receptacles are not recommended for use at operator positions. See “Grounding (Earthing) for Dispatch Centers and Network Operator Positions” on page 5-62.
- All 120 VAC receptacles **shall** have three conductors: phase, neutral, and ground (IEEE STD 1100-1999).
- Power cord plugs **shall** be supported with strain reliefs adequate to prevent accidental disconnection where applicable. Twist-lock plugs **shall not** be used in lieu of strain relief.
- All communications equipment receptacles **shall** have the electrical box or cover plate permanently marked with the service panel and appropriate circuit identification. This identification **shall** be readily visible without requiring removal of the plug.

- Receptacles meant to serve loads other than communication equipment **shall** be fed from the main distribution panel board and not from the equipment panel or the UPS. See “Power Quality” on page 6-11 for additional information.
- Outlet boxes or enclosures **shall** be securely mounted (NFPA 70-2005, Article 300.11 and 314.23). Cable ties **shall not** be used as a method of securing outlet boxes or receptacles.

6.2.11 RECEPTACLE STRIPS

- Extension blocks or receptacle strips **shall not** be mounted on the floor. Damage can result from foot traffic or water, and water seepage or fire sprinkler activation may pose an electrocution hazard to personnel.
- Receptacle strips are intended to provide AC power to low-power equipment where several line-powered items are closely collocated (such as an operator's position). In general, the following considerations need to be observed in selecting and installing receptacle strips:
    - If powering multiple similar devices from a receptacle strip, ensure that failure of the strip does not affect system availability. For example, do not plug all modems into the same receptacle strip.
    - Receptacle strips are limited to specific applications only where a receptacle strip is suitable for use. In all cases, receptacle strips **shall** be UL listed and of metal construction.
    - Receptacle strips **shall** be easily mountable without requiring disassembly.
    - AC power receptacle strips **shall** have a 3-prong power cord when used for permanent installations.
    - Receptacle strip **shall** be securely mounted to the supporting structure using intended bolt mounting and **shall not** be secured by being tie-wrapped.
    - Receptacle strips **shall not** include ON/OFF switches unless the ON/OFF switch is covered to help prevent the switches from being inadvertently switched off.
    - Consumer-grade surge-protected or locally fused receptacle strips **shall not** be used. Proper equipment setup and facility electrical design should accommodate these requirements.
    - No more than one receptacle strip **shall** be connected to the same branch circuit.
    - Redundant equipment pairs **shall not** be connected to the same receptacle strip.
    - Items considered individually critical (where no backup can easily be implemented) **shall not** be powered from a receptacle strip.
    - If multiple receptacle strips are used, they **shall** be plugged into dedicated simplex receptacles on individual branch circuits.

6.3 POWER QUALITY

Power quality is defined as “the concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment” (IEEE STD 1100-1999 and IEEE STD 1159-R2001). In order to operate reliably, electronic equipment **shall** be supplied with quality AC power.

The objective of Motorola site standards and guidelines is to establish benchmarks for designing optimum equipment operating environments. Providing quality power to electronic equipment is a key to system availability and system reliability.

See "Glossary" on page 1-11 for definitions of terms relating to power quality.

6.3.1 FUNDAMENTALS OF POWER QUALITY

This paragraph presents a brief introduction to power quality. See IEEE STD 519, IEEE STD 1100 and IEEE STD 1159 for additional information. The requirements and recommendations presented in this paragraph take into consideration established industry codes and standards for achieving operational environments that are suitable for electronic equipment. The American National Standards Institute (ANSI), British Standards Institution (BS), Institute of Electrical and Electronics Engineers (IEEE), International Electrotechnical Commission (IEC), and the Telecommunications Industry Association (TIA) have developed steps necessary for establishing a foundation to support the operation of electronic equipment.

The quality of power supplied to electronic equipment is influenced by, but not limited to, the following:

- Equipment load requirements
- Grounding (earthing) of the facility
- Sufficient delivery of power
- Interaction between connected loads
- Internal and external wiring
- Placement of the electronic equipment within the facilities

Many of the areas of concern affecting power quality are also addressed as minimum safety requirements specified by NFPA 70-2005 or other electrical codes in effect by the local authority having jurisdiction (AHJ). However, these minimum safety requirements are typically not sufficient to support the operation of electronic equipment.

6.3.2 COMMON CAUSES OF POWER QUALITY PROBLEMS

Table 6-1 summarizes some of the common causes of power quality problems. (See IEEE STD 1159-R2001 for additional information.)

TABLE 6-1 COMMON CAUSES OF POWER QUALITY PROBLEMS

Problem	Common Cause
Frequency Deviation	• Faults on the bulk power transmission system • Large block of load being disconnected • Large source of generation going off-line • Generator system faults
Voltage Sags (or dips) See Figure 6-5 on page 6-14 for example.	• System faults • Switching of heavy loads • Starting of large motors • Large load changes • Adverse weather conditions
Voltage Swells See Figure 6-5 on page 6-14 for examples.	• System faults • Single line-to-ground fault on the system resulting in a temporary voltage rise on the non-faulted phases • Switching off a large load • Switching on a large capacitor bank
Transients See Figure 6-6 on page 6-14 for example.	• Adverse weather conditions • Lightning • Load switching • Fault clearing • Capacitor discharge • Utility switching
Total Harmonic Distortion (> 5%) See Figure 6-7 and Figure 6-8 on page 6-14 for examples.	• Normal operation of nonlinear devices • Noise generating loads • Poor grounding (earthing) • Synthesized sine wave from a UPS or power conditioner

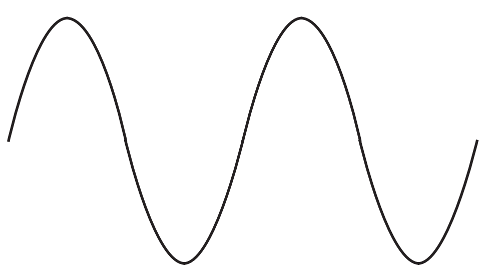


FIGURE 6-4 NORMAL SINUSOIDAL WAVEFORM

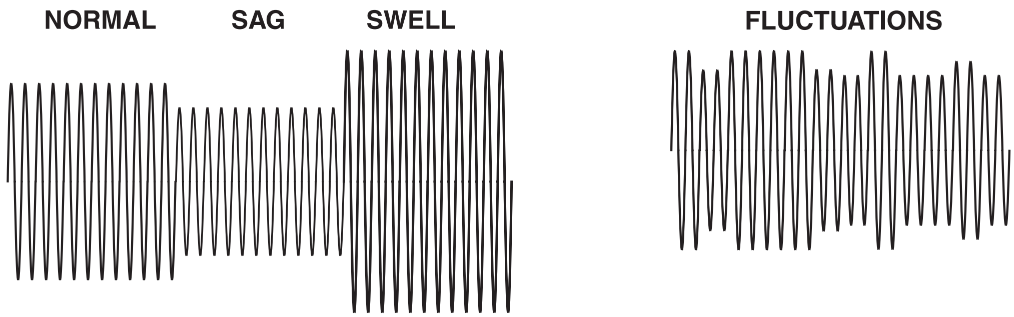


FIGURE 6-5 VOLTAGE SAGS, SWELLS, AND FLUCTUATIONS

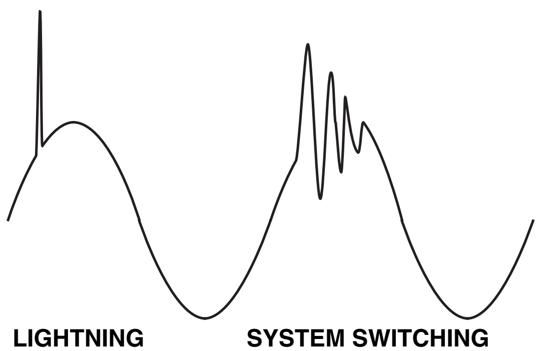


FIGURE 6-6 TYPICAL TRANSIENT VOLTAGES

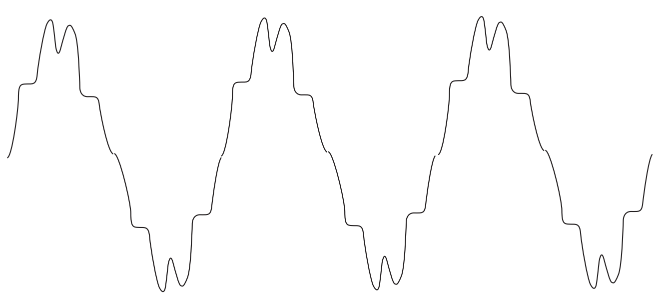


FIGURE 6-7 HARMONIC DISTORTION EXAMPLE

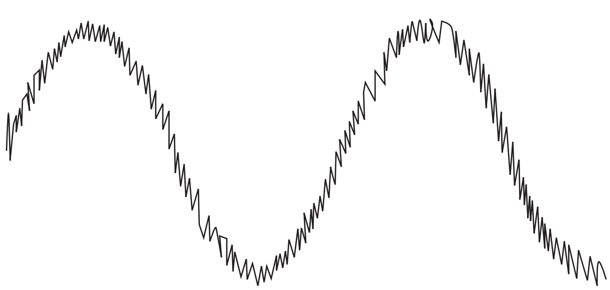


FIGURE 6-8 NOISE EXAMPLE

6.3.3 COMMON EFFECTS OF POWER QUALITY PROBLEMS

The following table summarizes the common effects of power quality problems on connected equipment:

TABLE 6-2 COMMON EFFECTS OF POWER QUALITY PROBLEMS

Problem	Common Effect
Frequency Deviation	• Writing errors in any electronic writing device • Incorrect clock timing
Voltage Sags (or dips)	• Equipment shutdown • Power supply interruptions • CPU lock up • Data errors
Voltage Swells	• Microprocessor failure • Progressive damage to power supplies
Transients	• Damage to microprocessors • Data errors or loss • Lock ups • Catastrophic failure of electronic equipment
Total Harmonic Distortion (> 5%)	• Failure of microprocessor controlled equipment • Overheating of electrical system components • Decreased life expectancy of electrical system transformers • Circuit breakers tripping

6.3.4 COMMON POWER QUALITY PROBLEM REMEDIES

The table below generalizes some common remedies of power quality problems. A power quality engineer may be required to help resolve power quality problems.

TABLE 6-3 COMMON POWER QUALITY PROBLEM REMEDIES

Problem	Common Remedy
Frequency Deviation[1]	• Report problem to the utility if the frequency deviation is measured on the AC utility • Make corrective repairs to onsite generator if the frequency deviation is measured on the generator
Voltage Sags (or dips)	• Corrective wiring • Relocation of critical loads • Power conditioners • UPS systems
Voltage Swells	• Surge Protective Devices (SPD) • Power conditioners • UPS systems
Transients	• Surge Protective Devices • Filters
Total Harmonic Distortion (> 5%)[2]	• Isolating the noise • Proper grounding • Power conditioners • Moving loads away from noise generators • UPS with a true sinusoidal waveform output (typically found with IGBT (insulated gate bipolar transistor) rectifier technology

1. Frequency variations are much more likely to occur when equipment is powered by an onsite generator, versus the AC utility (IEEE STD 1159-R2001).
2. See IEEE STD 519, Recommended Practices and Requirements for Harmonic Control in Electric Power Systems for additional information.

6.3.5 POWER QUALITY TESTING THRESHOLDS

The table below lists the recommended thresholds when testing AC power quality in most single-phase and three-phase configurations (IEEE STD 1100-1999). The actual thresholds used should be based on the installation requirements of the connected equipment, as the connected equipment may have more stringent requirements. See IEEE STD 1159-R2001 for additional information.

TABLE 6-4 MINIMUM RECOMMENDED AC POWER QUALITY TESTING THRESHOLDS

Category	Suggested Not-to-Exceed Thresholds
Phase Voltage Testing Thresholds	
Frequency Deviation	± 0.5 Hz
High Frequency Noise	Approximately 1% of the phase-neutral voltage
Voltage Sags	–10% of nominal supply voltage (108 V for a 120 VAC circuit)
Voltage Swells	+5% of nominal supply voltage (126 V for a 120 VAC circuit)
Transients	Approximately 100 V over the nominal phase-neutral voltage
Distortion	5% Total Harmonic Distortion (THD) – the voltage distortion level at which loads may be affected
Neutral-ground Voltage Testing Thresholds	
High Frequency Noise	2-3 V_{peak}
Voltage Swells	1% to 2.5% of nominal phase-neutral voltage

6.3.6 STEPS TO DEVELOPING A POWER QUALITY PLAN

Prior to deployment of electronic equipment, a power quality action plan should be established. To help determine necessary corrective action, the equipment's operating norms should be reviewed according to the manufacturers' stated requirements for optimal performance. Next, a complete assessment of the facility's current electrical environment should be conducted and compared to the requirements for the equipment. Load requirements, grounding, bonding, isolation and protection requirements should be considered.

To help maintain an optimal electrical environment, a power quality monitoring plan should be in place. The power quality monitoring plan should require regular review of the performance of the site's operating norms. This should include regular monitoring and recording of the site's power system, its connected loads, failures and interruptions. The objective of the power quality monitoring program is to identify problems and take corrective actions before incidental interference results in a wide area failure.

6.3.7 GENERAL RECOMMENDATIONS TO HELP PROMOTE GOOD POWER QUALITY

The following list presents some general recommendations to help promote good power quality. See IEEE STD 1100-1999, *Recommended Practice for Powering and Grounding Electronic Equipment*.

- Use a UPS or other source of backup power on critical loads.
- Use a UPS system that provides a true sinusoidal wave output to help maintain a total harmonic distortion (THD) below 5% (typically found in a UPS that uses IGBT rectifier technology).
- Isolate critical loads and electronic equipment from noisy or inductive loads (e.g. Motor driven cleaning equipment, space heaters, fans, copiers and printers).
- Separate critical loads/ electronic equipment and other loads onto different panelboards (IEEE STD 1100-1999).
- Install an insulated grounding conductor on receptacles that feed critical loads or electronic equipment, versus relying on the metallic conduit (IEEE STD 1100-1999, section 8.5.3).
- Match circuit availability to the load requirements (e.g., 15 amp circuits are not powering equipment that requires a 20 amp circuit).
- Maintain minimum separation between AC power conductors and other communications cabling.
- Restrict access to power control panels and mark electrical receptacles according to use (e.g., HVAC controls, electrical panels and switch boards, circuits for critical loads or other uses).
- Follow the recommendations/requirements of Chapter 7, “Surge Protective Devices.”
- Follow the recommendations/requirements of Chapter 6, “Power Sources.”
- Follow the recommendations/requirements of Chapter 5, “Internal Grounding (Earthing).”
- Follow the recommendations/requirements of Chapter 4, “External Grounding (Earthing).”
- Follow the recommendations/requirements of Appendix B, Protecting Against Electrostatic Discharge in Equipment Rooms and Dispatch Centers.

6.3.8 POWER QUALITY TESTING LOCATIONS

When monitoring a site that is serving several loads, it may be advantageous to initially install the power quality monitor at the power panel feeding the system to obtain an overall profile of the voltage. The power quality monitor can then be relocated to the circuits serving individual loads, or loads that are experiencing malfunctions and failures. Comparison of disturbance data can help locate the source of the disturbances and determine how to most effectively remedy the problem. (IEEE STD 1100-1999, section 6.4.2.5.)

Motorola recommends the following locations for testing power quality:

- To assess the power quality delivered to an individual piece of electronic equipment, test at the equipment's receptacle, especially if the equipment is exhibiting malfunctions and/or failures.
- To assess the quality of output power from a power conditioner or UPS system, test at the power conditioner or UPS power panelboard (or as close as practical).
- To assess the power quality of secondary distribution, test on the secondary of the equipment room transformer.
- To assess the overall power quality delivered to a facility, test at the facility's main electrical panel.

6.3.9 POWER QUALITY TESTING DURATION

The monitoring period is a direct function of the monitoring objective. Usually the monitoring period attempts to capture a complete power period, an interval in which the power usage pattern begins to repeat itself. For example, an industrial plant may repeat its power usage pattern each day, or each shift. Depending on the monitoring objective, it may be necessary to monitor as little as one shift. (IEEE STD 1159-R2001, section 7.5.1)

It is generally recommended that the minimum monitoring period include at least one full work cycle, normally seven or eight days. Longer monitoring periods are often needed to record disturbances that occur on a random or seasonal basis. (IEEE STD 1100-1999, section 6.4.2.5.)

6.4 RECTIFIER/DC POWER SYSTEMS

This section provides guidelines and specifies requirements for selecting and installing site rectifier/DC power system systems and components. Note that although specific recommendations are stated here, actual equipment specifications are largely determined by factors peculiar to the installation being performed. These stipulations are noted throughout the section.

6.4.1 RECTIFIER SYSTEM REQUIREMENTS

6.4.1.1 ACCEPTABLE RECTIFIER TYPES

Two general types of rectifiers are acceptable for powering communications equipment. The types are:

- Controlled Ferroresonant Rectifier

  A controlled ferroresonant rectifier exhibits an exceptionally good Mean Time Between Failure (MTBF), and typically provides an output exceeding 110% - 120% of its rating for the life of the rectifier. Forced load sharing is an essential feature of these rectifiers. In a multiple rectifier system, it prevents a single rectifier's output from drifting down and becoming inefficient.

  Both a potential drawback as well as benefit of this rectifier is its transformer. In an area prone to excessive AC transients, a controlled ferroresonant rectifier will continue to function satisfactorily. However, the transformer is large and heavy. Suitability of this rectifier type will be based on balancing these criteria.

  Although a ferroresonant supply is simple, low cost, and handles high current, it cannot handle AC line frequency shifts, particularly on the low side. An applied low line frequency (even 59 Hz) causes the ferroresonant supply to draw high current over excessive ON cycles. This overheats the transformer and causes close to short-circuit conditions within the tuned reactive circuit. A backup generator with a defective speed governor is a typical source of this trouble.

- Switchmode Rectifier

  A switchmode rectifier offers a size and weight advantage over ferroresonant rectifiers in that its transformer is smaller and lighter than controlled ferroresonant rectifiers. This type of rectifier will provides an output of 105% of its rating for the life of the rectifier.

  The drawback to the switchmode rectifier is that it does not have the large transformer to absorb transient surge voltages. These transient surges can shorten the life of the switchmode rectifier. In areas prone to significant transient voltages, controlled ferroresonant rectifiers may be a better choice. The lower MTBF of a switchmode rectifier can be offset by its ease of replacement. Also, the inefficiency at low output levels of these rectifiers is not nearly as severe as that of the controlled ferroresonant rectifier; therefore, forced load sharing is not required. A switch mode rectifier that is well-filtered to prevent radiated RFI and superimposed noise on the DC output circuit should be selected.

Silicon Controlled Rectifier (SCR)-based rectifier systems are not acceptable for powering Motorola systems, due to tendencies of SCRs to allow AC transients to propagate to the DC side.

6.4.1.2 REDUNDANCY

An n+1 redundancy setup is recommended, at a minimum, for the rectifier system. An n+1 redundant scheme employs one rectifier more than is required to power the system. In many cases, the redundant rectifier also provides for recharging of the batteries after a power outage.

6.4.1.3 RECTIFIER SIZING

In general, the power system selected should be appropriately sized based on the installation being performed.

- In systems requiring 1200 A or less, 2.5 kW (50A@-48V; 100A@24V) switchmode modular rectifiers (or equivalent) are recommended.
- In systems requiring more than 1200 A, modular rectifiers as described above are not typically recommended. This is based on the following:

  An n+1 redundancy using low capacity rectifiers may not provide sufficient reserve capacity to fully recharge discharged batteries within 24 hours. An n+2 or n+3 design may be necessary to handle recharge. However, this will affect overall system cost.

  Higher-output systems based on higher-current rectifiers have a theoretically higher MTBF. A -48 V, 1000 A non-redundant system using 50 A rectifiers will contain 20 modular switchmode 100 A rectifiers. The same system using 200 A controlled ferroresonant rectifiers will contain only five 200 A rectifiers. The 200 A rectifier system has 25% as many potential points of failure as the 50 A system.

6.4.2 DC DISTRIBUTION

The power board or DC power distribution center is the infrastructure around which the power system is built. A power board can be divided into two components: the meter/alarm and the control section/ distribution section. The distribution section of the power system can be reconfigured, expanded, and modified in many ways, however, when the meter, alarm, and control section is at capacity, any further expansion requires the replacement of the power board. Over sizing of the power board is relatively inexpensive because most of the over sizing consists of copper bus bars.

6.4.3 LOW VOLTAGE DISCONNECT

DC systems, with battery back-up, **shall** be equipped with a Low Voltage Load Disconnect (LVLD). A Low Voltage Battery Disconnect (LVBD) **shall not** be substituted for the LVLD. A battery system is considered to be fully discharged when the voltage reaches 1.75 VPC (volts per cell). In a 48 volt system (24 cells) the battery plant is fully discharged when the voltage reaches 42 volts (1.75x24). Battery damage begins to occur when the voltage drops below this point.

Continuing to operate the system beyond this point with the intent of providing service to the end user at the expense of damaging or destroying the batteries may not be possible. Internal power supplies that provide logic and memory voltages (typically +12V, -12V, and +5V) are designed to provide regulated power throughout a specific input voltage range. This range is typically within a few volts of the batteries operating range. When the input voltage drops below the specified range, the output voltage of the internal power supplies will no longer be within the specified limits. In many cases, the internal power system will shut down. If the internal power supplies do not shut down, damage or erratic operation may occur. Although a low voltage disconnect does protect the battery plant, it also is required to protect the load equipment.

6.4.4 OVERCURRENT PROTECTION

Because fuses may not always be available, appropriate circuit breakers are recommended.

Overcurrent protection should be a minimum of 50% larger than the **anticipated** load for the circuit. In-rush currents (the current draw when a device is first powered on) **shall** also be considered when sizing circuit protection. Overcurrent protection **shall not** exceed the ampacity rating of the conductors.

6.4.5 POWER CABLING CAPACITY

WARNING

UL-listed General Use or Battery cable shall be used.

The power cables that supply DC power to site equipment **shall** be sized based on their anticipated load requirements and current carrying capacity (referred to as "ampacity"). Ampacity is determined by the short-term amperage the conductor can carry before generating sufficient heat to degrade the insulation. Ampacity is determined by the following factors:

- ambient temperature
- insulation type
- heat dissipating characteristics of the cable transport

A conductor has a higher ampacity in free air that one that is enclosed in conduit because the conduit retains the heat. In certain electrical codes, a raceway is an enclosed duct that the cables are run through. As such, the ampacity rating of DC cable in a raceway is lower than that installed on the cable tray.

Independent of short-term ampacity, allowable voltage drop must also be considered when sizing power cables for DC systems. In many cases, this requires the DC power cables to be larger than the cable required for an AC system.

6.4.6 FLOOR AND CEILING RUNS, PLENUM GRADE AND RISERS CABLING

WARNING

Non-plenum rated power cabling shall not be installed within plenums. Failure to use plenum-rated cables in these areas can result in generation of toxic fumes in the event of a fire.

NOTE: Feasibility and methods of wiring within plenums and risers **shall** conform with jurisdictional codes.

The following requirements specify installation practices that help, should a fire occur, minimize smoke and products of combustion from electrical wiring in areas that handle environmental air. A plenum is defined as a compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system. See NFPA 70-2005, Article 100 for additional information.

- Wiring systems of any type **shall not** be installed in ducts used to transport dust, loose stock, or flammable vapors (NFPA 70-2005, Article 300.22(A)).
- Wiring systems of any type **shall not** be installed in any duct, or shaft containing only such ducts, used for vapor removal (NFPA 70-2005, Article 300.22(A)).
- Wiring systems may be installed in ducts specifically constructed to transport environmental air only when such wiring consists exclusively of the following. See NFPA 70-2005, Article 300.22(B) for additional information:
  - Type MI (mineral insulated) cable
  - Type MC (metal-clad) cable employing a smooth or corrugated impervious metal sheath without an overall nonmetallic covering

    - Type CMP (communications plenum cable), electrical metallic tubing, flexible metal tubing, intermediate metal conduit, or rigid metal conduit. Flexible metal conduit and liquid-tight flexible metal conduit **shall** only be permitted in lengths not exceeding 1.2 m (4 ft.), to connect physically adjustable equipment and devices permitted to be in the ducts. See NFPA 70-2005, Article 300.22(B) for additional information.

- Wiring installed in other spaces used for environmental air, such as the area above a suspended ceiling or as otherwise defined in NFPA 70-2005, Article 300.22(C), **shall** be installed in accordance with NFPA 70-2005, Article 300.22(C). Such wiring methods include using Type MI (mineral insulated) cable, Type MC (metal-clad) cable without an overall nonmetallic covering, and Type AC (armored cable) cable. See NFPA 70-2005, Article 300.22(C) for additional information.

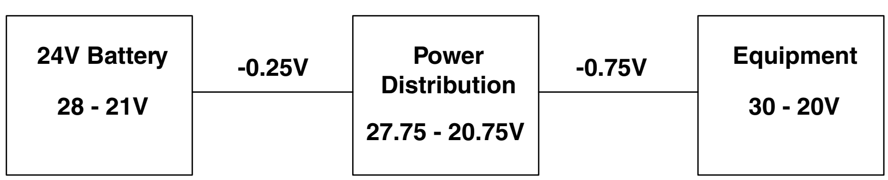
WARNING

Electrical installations installed in hollow spaces, vertical shafts, and ventilation or air-handling ducts shall be installed in a manner such that the possible spread of fire or products of combustion will not be substantially increased. Openings around penetrations through fire resistance-rated walls, partitions, floors, or ceilings shall be firestopped using approved methods to maintain the fire resistance rating. Firestopping such penetrations may be accomplished by using specially manufactured fire seals or fire-barrier caulking. See NFPA 70-2005, Article 300.21, ANSI/TIA/EIA-569-B, and NECA/BICSI 568-2001 for additional information.

6.4.7 DC POWER BUDGET

To properly size DC power cables, a DC power budget **shall** be established. Figure 6-9 shows an example power budget. Typical minimum DC operating range will be from 2.33 - 1.75 VPC. This translates to 56 - 42 V for a 48 V system, or 28 - 21 V for a 24 V system. (Some equipment will have an operating range wider than those stated here.)

The first step in establishing the DC power budget is to determine the lowest voltage in the equipment operating range, called the end voltage. Where multiple pieces of equipment are connected to a given branch, the highest of the end voltages should be used for the power budget. The difference between the equipment end voltage and the battery end voltage (1.75 VPC minimum) is the allowable voltage drop. Voltage drop from the batteries to the main distribution, main distribution to remote distribution, and remote distribution to the load is then determined by load and the distances between components.



In above example:
Battery End Voltage (21V) - losses (-0.25 - 0.75V) = 20V
Therefore, minimum equipment range must be 20 V or lower.

FIGURE 6-9 DC POWER BUDGET

If the equipment end voltage is equal to or higher than the battery's end voltage, then a higher battery end voltage will have to be selected. Using a higher battery end voltage will increase the battery size required for the system. Normal battery end voltages range from 1.94 - 1.75 VPC. In these cases, the allowable voltage drop should be kept to the absolute minimum practical.

6.5 UNINTERRUPTIBLE POWER SUPPLIES

This section provides guidelines and specifies requirements for selecting and installing a site Uninterruptible Power Supply (UPS). Note that although specific recommendations are stated here, actual equipment specifications are largely determined by factors unique to the installation being performed.

The UPS system is intended to provide short-term power to specific loads when commercial power glitches or short-term power outages occur. Most UPS systems come with a standard configuration that usually provides between 5 to 10 minutes of supply voltage at full load capacity. The UPS typically provides an alarm that indicates when the UPS is nearing battery depletion.

NOTE: Extended power delivery during a utility blackout is intended to be provided by a generator. The UPS is typically intended to provide transition power only between utility blackout and generator stabilization.

NOTE: If the site will use a generator in addition to a UPS, the UPS **shall** be programmed or configured to allow the generator to provide power and not block the generator from connecting to its intended load. Note that generator power may be rejected by a default-configured UPS because of sensing circuitry in the UPS that rejects the generator power as not being “pure,” as compared to its normally received utility-supplied power. Any AC “line quality sampling” feature on the UPS should be disabled to prevent the UPS from rejecting the generator as a power source.

6.5.1 DETERMINING UPS OUTPUT REQUIREMENTS

The following requirements and considerations **shall** be observed when specifying and installing the UPS:

- UPS **shall** provide true sinusoidal output. Step-synthesized output **shall not** be acceptable.
- UPS **shall** be capable of providing full rated output power for the switchover period from utility power to stabilized generator power.
- Service panelboard **shall** have enough capacity and breaker space to accommodate the UPS.
- Intended location of UPS **shall** have adequate capability to exhaust the heat generated by the UPS.
- Ambient temperature range near UPS **shall** be in accordance with manufacturer's specification.
- Adequate spacing for safe servicing of the UPS and battery banks **shall** be considered in planning the installed location of the UPS.
- Preventive maintenance (including suggested battery replacement intervals) **shall** be in accordance with manufacturer's specifications.

6.6 ALTERNATE POWER SOURCES

Certain sites without access to commercial AC power utilities can use solar and/or wind-generated power. The solar panels and/or wind generator charges batteries that provide power to site equipment. Propane or liquid natural gas (LNG) generators can be used, especially in colder climates, to back up the solar/wind system.

Because solar/wind systems provide limited power, it is important when planning the power system to calculate the predicted power usage for the site. Solar power is best suited for small sites with low power requirements where the physical size and cost of the standalone power system does not become impractical. The site's transmitter duty cycles **shall** be planned so as not to exceed the maximum average current requirements.

Wind generators can be used to back up a solar panel system. If there are sunless days with wind then battery charging can still take place. Such a system could take advantage of more sun in the summer and more wind in the winter. Wind generators should be mounted higher than buildings or other obstructions where wind flow is more efficient.

6.6.1 SYSTEM PLANNING

Development of a stand-alone power system should be contracted with a firm experienced in the design of alternate power systems. To design a system capable of supplying the site's power needs, the contracted firm needs the following information:

- Total typical ampere-hours (Ah) used by all site equipment over a 24-hour period. (1 ampere used continuously for 1 hour is 1 Ah.)
- Voltage the power system must be capable of providing. (Communications sites of this type typically use 12 volt or 24 volt battery systems.)
- The average number of consecutive sunless days expected at the location.

The daily AH rating is calculated as shown in the following example. Given the following characteristics for a single-repeater site:

Single repeater requires 7A for Tx (A_{Tx}) and 1A for Rx (A_{Rx})

Radio link requires 1.6A for Tx and 1A for Rx

Duty Cycle (Tx/Rx) of 20%

Using the following formula: **$[(A_{Tx} \times \%Tx) + (ARX \times \%Rx)] \times 24$ hrs = average Ah required**

For the example characteristics given, the repeater requirement is:
$[(7 \times 0.2) + (1 \times 0.8)] \times 24 = 52.8$ AH/day

Radio Link requirement is: **$[(1.6 \times 0.2) + (1 \times 0.8)] \times 24 = 26.9$ Ah/day**

Total requirement is: **79.7 Ah/day**

6.6.2 REQUIREMENTS

The following requirements and considerations **shall** be observed when specifying and installing a solar power system:

- Solar panels **shall** be located away from objects that could block sunlight to the panel. Panels **shall** be pole-mounted or roof-mounted if required.
- Observe the total time a particular location has direct sunlight throughout the day. Note in any calculation or specification that the site batteries are charged only when the solar panel is exposed to the sun.
- The angle of the sunlight with respect to the solar panel throughout the year **shall** be considered. Shadows cast by nearby objects may be different when the sun's angle changes with the seasons.
- Note that the fixed panel mounting angle for year round usage in northern latitudes is typically 10 degrees more than the latitude. For example, at a latitude of 45° north the panel should be mounted at an angle of 55° from the horizontal.
- The optimum angle varies throughout the year. The amount of variation increases with latitude. Have the panel supplier recommend the mounting angle. (Trackers are available that automatically move the panel to follow the sun, but these are rarely used at communications sites because of the additional maintenance and possibility of failure.)
- Solar panels **shall** be at least 10% oversized to ensure that they can handle the site's power requirements.
- Battery storage **shall** be adequate to supply power to the site for 5 to 10 days without wind or sun.
- Far northern latitudes (or far southern latitudes in the southern hemisphere) have less daily sun charging time.
- Deep-cycle batteries **shall** be used in systems experiencing up to 80% of the battery system is discharged and recharged.
- Solar panels and wind generators **shall** be mounted high enough to discourage vandalism. Bullet-resistant solar panels are available.
- Where applicable, panels **shall** be mounted high enough to clear deep winter snowfalls or ice accumulation.
- Panels **shall** be mounted and supported such that damage by high winds is avoided.
- Outside cabling **shall** be well secured and protected with conduit, or run inside the mounting pole.
- Plan the battery location in accordance with “Battery Systems” on page 6-27. In earthquake-prone areas (Moment Magnitude rating 3 or greater), batteries **shall** be mounted in seismic-rated battery racks secured to the floor.

6.6.3 INSTALLATION

Install the solar panels and wind generator in accordance with instructions provided by the contracted design firm.

- If panels are roof-mounted, the metallic portions of the solar panel framework **shall** be bonded to the site grounding electrode system in accordance with Chapter 4, "External Grounding (Earthing)."
- If panels are pole-mounted, the pole ground **shall** be bonded to the site grounding electrode system in accordance with Chapter 4, "External Grounding (Earthing)."
- It is recommended that cabling from the outdoor portion of the system be protected in conduit and secured. Cable from pole-mounted solar panels or wind generators can be run inside the mounting pole. Appropriate precautions **shall** be taken to protect the cable from moisture ingress.
- Batteries **shall** be installed in accordance with "Battery Systems" on page 6-27 and secured against earthquakes in seismically active areas (Moment Magnitude rating 3 or greater) using a seismic-rated battery rack rated for the site's seismic zone. Secure the rack to the floor per manufacturer's instructions.

6.6.4 MAINTENANCE

- Solar panels **shall** be cleaned and inspected twice a year or as required to prevent accumulation of bird droppings, dust or pollen that could reduce efficiency by blocking sunlight.
- Cracked or damaged panels **shall** be replaced.
- Manufacturers' instructions for maintaining batteries **shall** be observed.

6.7 BATTERY SYSTEMS

Batteries used for equipment backup can be divided into two categories: flooded cell (wet) and valve regulated (sealed). Flooded cell batteries pose greater hazards, because they emit hydrogen gas during normal operation. Sealed batteries do not typically vent hydrogen.

Where applicable, it is recommended that certified Hazardous Materials handlers be contracted to handle tasks involving the hazardous materials contained in most battery systems.

6.7.1 BATTERY SAFETY

WARNING

Motorola employees and contractors shall not handle hazardous materials unless properly trained. This includes warehouse storage, transportation, and installation of battery systems.

WARNING

Wet cell battery failure involving large-scale electrolyte leakage may constitute a Hazardous Material (HAZMAT) condition. Under no circumstances shall regular site personnel perform HAZMAT handling. Special training and HAZMAT certification, spill mitigation and reporting, and cleanup techniques/monitoring is required under the Federal Clean Water Act and NFPA regulations.

WARNING

Batteries used for powering equipment pose the following risks. Always use appropriate caution when working with and around batteries.

Explosion hazard resulting from inherent generation of hydrogen sulfide gas;
Chemical burn/blindness resulting from sulfuric acid electrolyte. Wash affected skin or eyes immediately with running water. Seek medical help immediately.
Very high current capabilities, with the possibility to burn, start fires, and result in arcing.

NOTE: Material Safety and Data Sheets (MSDS) describing the nature of HAZMAT materials present at a communications site, their reactivity, flammability, and emergency spill/release mitigation and reporting are required at each site.

All applicable NFPA, OSHA and local codes **shall** be followed regarding battery installations and maintenance work.

Battery manufacturer warning statements **shall** be understood and complied with. The manufacturer's statements **shall** determine the type and extent of Personal Protective Equipment required in minimizing battery handling hazards for the batteries being installed.

This section provides safety rules to be followed when working with wet cell batteries. Wet cell batteries require more stringent handling and safety precautions than dry cell batteries. In all cases, manufacturer's documentation **shall** be read and understood before installing or maintaining battery systems. Placards placed directly on the battery define the precautions required. See "Typical Battery Safety Kit" on page 3-30 for the required equipment to be provided at the site for working with batteries.

Observe the following general considerations regarding battery installation and maintenance:

- At all sites using wet cell batteries, or gel-cell batteries where manufacturer specifies eyewash or other Personal Protective Equipment, such equipment **shall** be provided in the battery containment area.

NOTE: Discard and replace bottled eyewash solution according to the expiration date on the bottle.

- Because of the chemical composition, weight, and bulk of many battery configurations, certified transporters and hazardous materials handlers may be required.
- Batteries may require two-person lift. Use proper lifting techniques and equipment to avoid injury.
- Installation personnel **shall** wear necessary safety equipment when installing batteries.
- "NO SMOKING" signs **shall** be prominently displayed in the battery room and on the exterior of the battery room entry door. Smoking, or the source of any spark producing materials, **shall** be strictly prohibited in this area.
- Batteries **shall** have insulated covers and/or insulated terminal protectors.
- Batteries **shall not** be used as a work surface.
- Batteries **shall** be covered when work is in progress above them.
- The US Federal Clean Water Act, with jurisdictional or local option by location, does not allow battery acid spills, which are neutralized, to be flushed down the drain or spilled on soil. Dispose of spills as required by local regulation.
- Jewelry **shall not** be worn while working on batteries.
- Insulated tools **shall** be used when working around batteries to minimize the potential for an accidental short circuit.
- A lightweight, acid resistant bib type apron in good working condition **shall** be permanently stored on site near the battery plant. The fabric **shall** be acid, caustic, puncture, and flame resistant.
- An acid resistant, full face shield in good working condition, **shall** be permanently stored on site near the battery plant. The shield **shall** meet all requirements of ANSI Z87.1. Protective eye wear that does not provide full face protection is not allowed.
- One pair of acid resistant gloves in good working condition **shall** be permanently stored on site near the battery plant. These gloves **shall** be of sufficient length to cover the hand, wrist, and forearm for protection from chemical splash.
- One 0.5 kg (1 lb.) box of baking soda or equivalent acid neutralizing compound **shall** be permanently stored on site near the battery plant. Water is required to mix with the baking soda.

NOTE: Discard and replace bottled eyewash solution according to the expiration date on the bottle.

- An OSHA approved emergency eyewash station **shall** be permanently mounted near the battery plant. The eyewash station **shall** use an isotonic saline wash capable of neutralizing acids or caustics and **shall** be able to flush the eye for 15 minutes. A plumbed eyewash station and a shower should be provided in battery areas if possible.
- A container of non-oxidation material for coating electrical connections **shall** be left on site.

- Where applicable, provisions **shall** be made to exhaust gases produced by batteries For wet cell batteries the manufacturer-specified stationary battery flame-arresting vent **shall** be installed on each cell. This vent **shall** be secure, clean, and in good repair to help ensure maximum protection against potential explosion. Sealed batteries do not have an opening for adding electrolyte. However, there is generally a small vent hole that opens as required to vent internal gasses. There are two methods which may be used to vent battery gases:
  - Use an exhaust fan on a timer, changing the total room air four times per hour.
  - Use a manifold system that consists of tubing connected to each cell and vented to the outside.

NOTE: In most cases, sealed batteries do not require venting. Check local codes for applicability. Check the labels on the batteries for the proper protection based on that particular type of battery.

- Batteries **shall** be kept clean to reduce short circuit hazards, rack corrosion and the possibility of electrical shock. Clean batteries with clear water if necessary. Do not use abrasive cleaners, detergents or petroleum-based cleaning products on battery container.
- Battery banks consisting of multiple cells with circuit protection greater than 20 amperes **shall** have 12.7 mm (0.5 in.) or greater thickness polycarbonate or hard rubber protective shield installed on a support frame and securely mounted in front of the battery rack to protect personnel should there be a violent structural failure of any cell(s). This protective shield **shall** extend from 76 mm (3 in.) above to 76 mm (3 in.) below the height of the cells being protected.
- When batteries are located in an area that is accessible to persons other than qualified system maintenance personnel, an additional protective shield as described above **shall** be installed to cover the top of all cells and battery circuit conductors to prevent conductive materials from contacting battery posts or circuit conductors on top of the cells.

6.7.2 BATTERY CONTAINMENT AREA

The following requirements and considerations **shall** be observed when specifying and laying out a battery containment area:

- Certain areas may require use of UL listed Intrinsically Safe vent fans, electrical, and electronic equipment. See NFPA 70-2005, Article 500 through 505.
- NFPA signs advising the fire department of reactivity with water **shall** be posted. (NFPA 70E, Section 1-8.2.3).
- Separate battery rooms (especially for flooded cell types) that are sealed from adjoining rooms and properly vented to the building exterior are recommended. These conditions may also be required by local codes.
- Where battery systems use a total electrolyte volume greater than 3.79 L (1 gallon), cell assemblies, and containment/neutralization provisions **shall** conform with NFPA 111.

WARNING

Appropriate signage shall be present on doors leading to battery rooms and within the room itself, notifying personnel of explosion, chemical, and electrical hazards within the area. Appropriate fire extinguisher(s) shall be present in battery room, as dictated by local code.

At sites where batteries constructed with bolt-on terminal connections are used, the following items **shall** be provided:

- Connector bolt wrench (nonconductive)
- Lifting sling and spreader block if applicable
- Container of non-oxidation material for coating electrical connections
- At sites with flooded lead-acid batteries, the following items **shall** be provided:
  - Hydrometer with markings every 10 points
  - Acid-resistant container for storing the hydrometer
  - Thermometer, battery

6.7.3 BATTERY BACKUP DURATION

Typically, a two hour battery backup provision is standard practice for shelter installations. This is based on the assumption that 2 hours is the nominal amount of time in which a technician would be able to respond and correct a site power problem for most urban locations. For remote sites, 4 hours or more may be necessary to respond and take action.

Battery backup requirements can range from a few minutes to many hours, depending of the system application and customer requirements. Backup of less than one hour is considered to be a high rate of discharge application.

NOTE: Because the battery backup typically will not provide for power to the HVAC system, temperature related shutdown (due to temperature shutdown circuitry in repeaters) **shall** be considered in determining the maximum operational period under backup conditions. In some cases, thermal shutdown can occur well before basic battery exhaustion.

6.7.3.1 HIGH RATE OF DISCHARGE

If the battery plant will be used in a high rate application, or if an existing plant is to be converted to a high rate application, consult the battery manufacturer because this may require batteries specifically designed for high rate applications. High rate plants may require that the size of hardware used to connect the cell into a string be sufficiently large as to accommodate the additional heat generated by high rates of discharge.

6.7.3.2 LONG DURATION BACKUP

Battery backup of many hours may be desired, and can be designed for, but may not always be achievable. Long term outages are caused by loss of AC from the utility company and/or the standby generator. During long term outages, the HVAC (heat, ventilation, and air conditioning) system is also disabled. Depending on the site and the equipment being powered by the batteries, significant thermal rise or fall may occur. If the outage persists long enough, thermal shutdown due to loss of HVAC may be the true limiting factor in backup duration. Given the heat generated by the equipment and a potential range of outside ambient conditions, an HVAC contractor should be consulted to determine the amount of time it will take for the site to reach the high or low limits of the equipment's operating temperature range. For worse-case calculations, battery backup durations exceeding this time are not recommended.

6.7.4 BATTERY SIZING

Battery sizing can be straightforward or fairly complex, depending on the characteristics of the load being backed up. Stationary batteries (those used for fixed locations) are rated in Amp-Hours (AH).

An 8-hour duration represents a rated amperage. The amp hour rating of stationary batteries is generally stated as the number of amps a battery can deliver for an 8-hour period. For example, 100 A for 8 hours is a 800 AH battery. If durations of other than 8 hours are desired, a correction factor must be applied. Table8-1 provides the correction factors for several durations. Note that new batteries do not deliver 100% of their rating. It takes several charge/discharge cycles to bring a battery plant to full capacity. Also, as a battery continues to age its capacity gradually falls to 80% of its initial rating, at which point it is considered to be at end of life. These characteristics should be considered when choosing batteries.

TABLE 6-5 BATTERY RATING CORRECTION FACTORS

1 Hour	2 Hours	4 Hours	6 Hours	8 Hours
1.763	1.378	1.157	1.061	1.0

The DC load for most digital systems can be assumed to be steady-state, as it does not vary (even during busy times). Multiply the load by the back-up duration, and apply the correction factor, if necessary.

For example, given a load of 32 amps and a back-up duration of 4 hours, multiply the load (32) by the duration in hours (4) and the correction factor of 1.157. This means that a battery with at least a 148 amp hour rating will be required for this application.

To calculate battery size, the power required and duration of each change must be known. Graph out the entire discharge profile. When the discharge profile is graphed, divide the discharge into blocks based on duration.

6.7.5 BATTERY RATING

Batteries **shall** be accurately sized to ensure they will maintain proper voltage for the required time duration. Use worst-case scenarios with respect to age/deterioration, lowest temperature, expected load, and the availability of alternate power generators.

6.7.6 MULTIPLE BATTERY STRINGS

General practice stipulates that battery types, ratings, and service life **shall not** be mixed among a rack. If a site is expanded, then all fresh, similar batteries **shall** be installed and the old batteries removed. A mixture of batteries results in unequal current distribution and charging, and the probability of ongoing power system problems as batteries of different ages fail.

Floor loading, growth, and system load are a few of the factors that determine the number of strings of batteries required. All battery backup systems require maintenance. Some of the maintenance operations require the batteries to be off-line. Because there is no way to predict a short duration power interruption, a minimum of two strings of batteries is strongly recommended. This will ensure some amount of battery backup should an interruption occur during battery maintenance.

Too many strings of batteries also presents a problem. Should a fault occur in one cell in one string of batteries, diagnosing and locating the fault becomes more difficult as the number of strings increases. To protect the battery plant from a catastrophic failure of a single string of batteries, overcurrent protection is necessary for each individual string in the plant. The sizing of this protection should be as follows:

System amp capacity/Number of battery strings -1 = Required protection

Manufacturer recommendations for the maximum number of strings varies widely. Motorola recommends that the power system be initially designed for a minimum of two strings and a maximum of six strings of batteries when the system is fully implemented. This will allow some margin for excess growth should the system exceed the anticipated load of a fully implemented system.

6.7.7 BATTERY CHARGING

Batteries that have been discharged to a state below full charge must be fully recharged within 24 hours. During this process considerable charging current may flow and flooded cell batteries will give off a higher level of gas than during normal float charge. A float charge must be maintained to keep the battery in a fully charged state. Over or under charging of batteries will cause an increased need for battery maintenance and may greatly shorten the service life of the battery. It is important that the charging system is properly adjusted per the manufacturer's specifications. Overcharging and undercharging alarms **shall** be installed to ensure that battery charging problems are detected quickly.

6.7.8 BATTERY TEMPERATURE REQUIREMENTS

Battery performance and service life are significantly affected by operating temperature. For full-rated performance and maximum service life, the battery temperature should be maintained close to 24° C (75° F). The battery operating time is reduced as the temperature falls; conversely, the operating time is increased as the temperature rises. However, when batteries are subjected to elevated temperatures the service life of the battery is reduced.

Reference temperature is often overlooked in rating batteries. Battery manufacturers typically use 22.2° C (72° F) as the reference temperature. A battery operated at 0° C (32° F) produces 30% capacity, but lasts for 130% or more of the rated life. Conversely, a battery operated at 38° C (100° F) produces 130% battery capacity, but may last less than 1 year.

NOTE: If building codes do not allow batteries within the same compartment as the climatized radio equipment enclosure, outdoor battery pedestals may have to be protected from direct sunlight or elevated to prevent their burial in snow during winter (where applicable).

6.7.9 BATTERY INSTALLATION

Personal protective equipment, as dictated by battery manufacturer warning statements, **shall** be available within the battery area. A plumbed eyewash station and emergency shower should be provided if possible.

WARNING

To avoid spilling acid, do not tip batteries. Battery acid can cause severe burns and blindness if it comes into contact with skin or eyes. Wash affected skin or eyes immediately with running water. Seek medical attention immediately.

- Jewelry **shall not** be worn while working on batteries.
- Installation personnel **shall** wear necessary safety equipment when installing batteries.
- Batteries may require a two-person lift. Use proper lifting techniques and equipment to avoid injury.
- Insulated tools **shall** be used when installing battery systems.
- Battery installation **shall** conform to manufacturers specifications, the National Electrical Code (or equivalent), and all applicable national, state, and local codes. Observe the following cautions when installing batteries:
- Do not slide or drag batteries.
- Because of size, weight, and service needs, batteries are normally installed on shelves or racks. In earthquake-prone areas (Moment Magnitude rating 3 or greater), however, seismic racks **shall** be used. Seismic racks **shall** be properly secured to the floor or wall, but **shall** not be secured to both. Seismic racks **shall** be installed exactly as specified by the rack manufacturer.
- For areas with seismic rating of Moment Magnitude rating 3 or greater, appropriate rack design **shall** be used. Follow manufacturer's installation requirements.
- Racks and shelves **shall** be constructed to support the total weight of the batteries and other supporting equipment placed on them. Racks and shelves **shall** be assembled in accordance with the manufacturers specifications.
- Battery racks **shall** be bolted to the floor or wall.
- The batteries **shall** be prevented from falling due to accidental movement by installing a rim to prevent tipping, or by interconnecting batteries to prevent movement.
- Metal racks **shall** be grounded in accordance with specifications provided in Chapter 5, “Internal Grounding (Earthing).”
- Perform calculations to ensure that the floor area will support the total weight of the rack and the batteries. See “Battery Installation” on page 6-34.
- All terminal connections **shall** be tightened to manufacturers' specifications.
- A non-sparking circuit breaker of suitable size to handle maximum load and charging currents **shall** be installed in the ungrounded leg of the circuit to provide overcurrent protection. The ampacity of the circuit breaker **shall not** be greater than the ampacity rating of the circuit conductor. This device may also serve to disconnect the load during battery servicing.

- Circuit conductors, including jumpers between several cells, **shall** be jacketed copper of at least the minimum AWG size permitted for the maximum DC load. Conductor size may need to be larger than that specified to minimize voltage drop between the batteries and the equipment.
- In the U.S., DC conductor jacket colors **shall** be red (floating or ungrounded) and black (grounded). Red and black tape may be applied at each connection, splice or pull box if red and black conductors are not available. These requirements may vary by vendor product and international location.
- Conductors **shall** be enclosed in PVC or metallic conduit or raceway for protection from physical damage and **shall not** be exposed except near terminations.
- Any additional disconnect switches **shall** have an ampacity rating equal to or greater than the circuit protection device.
- Battery terminals **shall** be protectively coated in accordance with manufacturer's specifications.
- Exposed battery terminals should be protected from accidentally contacting metal objects.
- Stationary lead acid batteries **shall** be equipped with an approved spill containment system to prevent damage caused by spilled battery electrolyte whenever electrolyte capacity is greater than 4.8 liters (1 gallon). NFPA 70-2005, Article 480, BOCA 307.8.13, Universal Building Code Article 304.8. The spill containment system **shall** comprise a passive and active neutralization system.

6.7.10 BATTERY MAINTENANCE DISCONNECT

At some time it will be necessary to perform off-line maintenance on the batteries. An individual disconnect **shall** be supplied for each string of batteries for isolating a string from the rest of the system to safely perform battery maintenance. The disconnect device **shall** be such as to prevent arcing upon circuit make/break, and prevent any exposed live conductors.

Ensure that the DC supplied by the rectifier is electrically clean enough to supply equipment without the filtering characteristics of the batteries attached. Equipment damage could result if rectifier output has to much ripple.

6.8 STANDBY GENERATOR SYSTEMS

NOTE: The expected need of having a site supplied with a standby generator should be balanced against the economy of including a generator at the site. It is most likely cost-prohibitive to provide standby generators for large systems utilizing many sites. Typically, only difficult to access or remote location sites are equipped with standby generator power. An “Appleton”-type power connector can be installed at sites not equipped with a generator. In these cases, a portable generator can be conveniently connected to the site if needed.

This section describes requirements for backup/standby generators. The purpose of a backup or standby generator is to supply reliable power to critical loads during times when commercial power has failed. It is very important that generators used for this purpose be capable of reliably handling the required loads for the desired time while maintaining proper voltage and frequency. Backup/standby generators are not required to be installed to the same standards as emergency generators. The standards included in this section do not apply to emergency generators or power systems. Emergency power systems are required to comply with NFPA 70-2005, Article 700. Therefore, it is recommended to know and understand the difference between back-up/standby generator and emergency generator systems before procuring a generator equipment or installation work.

NOTE: There are certain locations where commercial power is not available and generators must be used for primary power. Primary power generators or generating systems **shall** be rated for continuous duty and **shall**, at a minimum, be installed to the standards covered in this section. All domestic installations **shall** meet NFPA 70-2005, (National Electrical Code (NEC)), and any other local governing codes applicable to continuous duty, primary power generators. Installations performed in non-domestic locations **shall** meet all applicable national and local codes. (NFPA 110)

A generator system includes the generator, along with a cooling system, a fuel supply system, a transfer switch, and a control panel with required alarms. Liquid fueled generators may incorporate the fuel tank into one housing, such as a base mounted tank. The transfer switch and control panel may also be incorporated into one cabinet. The generator may be placed outside as a stand-alone piece of equipment or inside a building or structure. The location may depend on several factors that include generator size, fuel supply, noise restrictions and space availability. Local codes may additionally dictate the fuel type allowed.

6.9 GENERATOR OUTPUT AND DERATING CONSIDERATIONS

To ensure that the backup generator can handle the power requirements of the equipment at the site, always consider the following factors when calculating generator output power requirements:

- Voltage, phase, and load requirements of the equipment to be supplied by the generator must be obtained, including unusual loads such as UPS power supplies and switched power supplies. The customer or an electrical engineer may specify these values.
- Consider site expansion. A 30% expansion factor is not unreasonable.
- Consider worse-case scenarios for generator load, such as all transmitters keyed simultaneously at a trunking site.
- Consider whether the generator load will be 3-phase or single-phase. Many generators are rated for operation with a 3-phase load and must be derated when working with a single-phase load. If the load is single phase, be certain that the generator is capable of supporting the maximum load while connected in a single-phase configuration. When balancing the single phase loads across three phases, always account for transmitter current.
- Consider physical requirements of the site. Generators may be derated based on operating altitude, type of fuel, and operating temperatures.
- The generator **shall not** be used under conditions that could exceed the manufacturer's specifications for the particular generator equipment.

6.9.1 GENERATOR PLACEMENT

All generators **shall** have an adequate supply of fresh air to ensure proper operation and extend life. Air is required for safe and efficient combustion as well as to cool the engine and generator. The type of engine cooling is determined by the capacity of the generator. Most generators above 7.5 kW utilize water-cooled engines; generators below 7.5 kW typically use air-cooled engines. The rate of airflow required for cooling is specified by the manufacturer. Manufacturer's guidelines **shall** be followed to ensure proper operation.

NOTE: The type of fuel used for a generator dictates the elevation of the fuel tank relative to the generator. A liquid-fuel generator (diesel or gasoline) will require that the fuel tank be upgrade from the generator fuel inlet such that the generator remains primed. Conversely, because gases rise, an LPG or natural-gas powered generator **shall** be placed upgrade from the fuel source outlet port.

6.9.1.1 GENERATORS LOCATED INDOORS

If the generator is to be located inside a separate structure or within the site building, the following requirements **shall** be met:

- Personnel safety and vulnerability of the generator to damage **shall** be considered, especially if the generator is to be installed without a protective housing. Moving engine parts and the exhaust system may be exposed, which could pose a hazard. Guards or shields **shall** be installed on exposed engine parts that could pose a safety hazard to personnel.
- The generator **shall** be located in an area accessible only by authorized personnel.
- Provide adequate spacing for service to the generator in accordance with NFPA 70-2005 and state and local codes (or equivalent). Generally, a minimum spacing of 914 mm (3 ft.) on three sides is acceptable.
- Manufacturer's specifications **shall** be followed to ensure proper ventilation, fuel supply, and engine exhaust.
- Properly sized air intake and exhaust ports **shall** be installed and maintained. The exhaust air from the radiator area of the generator in most cases is ducted to the outside.
- A louver or shutter should be installed on the exterior of the duct to close off the duct when the generator is not running. The shutter should open automatically when the generator begins operating
- A motorized louver or shutter should be installed on the air intake to close off the duct when not in use. The shutter should open automatically when the generator begins operating.
- The concrete foundation for the generator should be separate from that of the general structure. An inset sub-foundation set within a well in the overall foundation will help isolate transmitted vibration and noise emanating from the generator.
- Ensure that there is an adequate fresh air supply. Should the fresh air supply not be adequate, air will be drawn through doors, or possibly through existing vent pipes, causing a down draft of these vents. This could draw undesirable or potentially harmful fumes or gases back into the room or building. This could be a major concern in manned buildings. Check local codes for recommendations and guidance in this area.
- Fuel supply lines **shall** be no smaller in diameter or of greater length than that specified by the manufacturer. These lines should be routed and installed such that they are protected from potential damage.

- The engine exhaust system pipe and muffler **shall** be no smaller in diameter or of greater length than that specified by the manufacturer.
- In areas where the noise levels exceed 85 dBA, warning signs and hearing protection **shall** be provided.

6.9.1.2 GENERATORS LOCATED OUTDOORS

If the generator is to be located outdoors, the following requirements **shall** be met:

- The generator **shall** be enclosed in a housing sufficiently rugged to protect against weather, animal/insect ingress, and tampering. This is especially important for the radiator and fuel tank.
- The generator **shall** be enclosed within a fenced area, with adequate distance between the fence and the equipment for servicing.
- A muffler **shall** be used to minimize noise. If the generator is installed near other buildings, a muffler suitable for use in residential areas **shall** be used.
- The engine exhaust **shall** be equipped with a rain cap.
- Locate the generator such that wind will not likely carry dust and moisture into the housing nor exhaust gases into the building.
- Locate the generator such that required ventilation may be achieved. Most generators exhaust air outward through the radiator.
- In colder climates other considerations apply. An engine block heater may be required to keep the engine oil usable.
- Grade relative to fuel source/fuel inlet **shall** be appropriately considered.

6.9.2 FUEL SUPPLY

Generators may be operated from diesel, liquid propane or gaseous (propane or natural gas) fuels. Domestically, state and local codes **shall** be observed because different areas of the country have unique requirements. Fueling requirements in non-domestic locations **shall** meet all applicable national and local codes.

When selecting a generator, determine the standard fuel source for the area and use it whenever possible to ensure that an adequate fuel supply is available. Where available, utility-provided natural gas provides the most reliable fuel source and releases the installation from concerns regarding fuel tanks.

In general, the following fueling considerations **shall** be observed:

- **Liquid Propane Gas (LPG)** is considered the best all-around backup generator fuel. If possible, an LPG-configured generator should be considered.
- **Diesel and gaseous propane** are not well-suited for cold climates. Diesel is no longer allowed for new generator systems on US Federal lands due to ground contamination concerns. Diesel requires regular anti-bacterial treatment and water drainage. Diesel must be replaced with fresh fuel periodically.
- **Natural gas** requires a reservoir tank in addition to the supply line. If the supply line is severed, then the generator immediately stops. If natural gas is used, the generator output power will typically be reduced by 20%, as compared to gasoline. Generator output must be derated accordingly in these cases.

- **Gasoline** is a poor fuel for remote generators, with a limited storage life and highly flammable properties. Gasoline generators also have difficulty with remote starting.
- Liquid fuel storage tanks **shall** be equipped with secondary containment capable of retaining 110% (or greater) of the maximum volume of fuel stored.
- The storage tank secondary containment **shall** be designed such that storm water and debris cannot collect inside it.
- All fuel lines or other system components that extend beyond the storage tank secondary containment area **shall** be designed with secondary containment.
- Local Environmental Protection Agency (EPA) rules **shall** be adhered to following a fuel spill. All fuel spills **shall** be cleaned up.
- Fuel storage tanks are required for all fuels except natural gas, which is provided by a utility. (However, a storage tank in conjunction with utility-provided natural gas provides additional backup in the case of gas main breakage.) Manufacturer specifications as to size and length of fuel supply lines as well as lift **shall** be followed.
- Fuel storage tanks located outside of a structure should be protected from damage and tampering, and **shall** be enclosed within a fenced area. In many areas local codes require a double wall construction for the tank or a catch basin to prevent fuel from contaminating the site. Minimum recommended distance between the storage tank and fence is 1.2 m (4 ft.); minimum recommended distance between the tank and site building is 3 m (10 ft.). See NFPA 58 for additional information.
- Fuel storage tanks **shall** be secured to concrete pads using captive hardware.
- LPG fuel tanks **shall** utilize a fuel vent pressure relief valve. The relief valve vent **shall** be directed away from the tank, sources of ignition, and flammable material.
- Fuel lines **shall** be protected within the fuel storage area as well as along the route to the generator. Location and installation of the fuel tank and fuel lines **shall** meet all applicable environmental, building, and fire safety codes.
- All generator installations **shall** be equipped with secondary containment capable of retaining 110% of the volume of the largest tank within the containment structure, if the tanks system is a single-wall system. Alternatively, if the tank system is a double-walled system, the system **shall** be designed with interstitial monitoring devices that is capable of detecting a leak in the primary or secondary containment system unless tertiary containment is provided (for example, a convault or equivalent). Special tanks (double wall or fiberglass) and containment barriers are strongly recommended. Earthquake prone areas may require special fuel line considerations. Local codes and manufacturer's recommendations **shall** be followed.
- In potential flood zones, above ground fuel tanks should be secured with a safety cable around the tank attached to an anchoring device in the soil. This helps prevent the tank from breaking loose and floating away during a flood condition.
- Critical placement and orientation of the tank pressure relief valve is required. This is required, in the case of a fire, to prevent an over-pressure gas release cloud from feeding its own fire.

6.9.3 TRANSFER SWITCH

A transfer switch **shall** be installed to perform the switching between commercial power and standby power. This switch is generally collocated with the site electrical service panel. In general, the following considerations need to be observed:

- The switch **shall** have an ampere rating equal to or greater than the ampere rating of the circuits to be transferred.
- The transfer switch is generally located inside a building; however, if the transfer switch is enclosed in an approved watertight housing it may be located outside.
- Many areas require a disconnect switch in the feeder cabling between the generator and the transfer switch. This facilitates generator servicing and provides an additional safety device to prevent AC power backfeed into the commercial service.
- The neutral-ground bond **shall not** be made in the transfer switch.
- For domestic sites, installation of the transfer switch **shall** follow the manufacturer's recommended installation guidelines as well as meet all applicable NFPA 70-2005, national, state and local codes. Installations performed in non-domestic locations **shall** meet manufacturer's recommended installation guidelines, as well as all applicable national and local codes.
- Surge suppression **shall** be installed. See Chapter 7, “Surge Protective Devices.”

6.9.4 ELECTRICAL WIRING CONSIDERATIONS

When designing the interconnection wiring between the generator, transfer switch, and site AC mains, the following considerations **shall** be observed:

- There **shall** be two sets of circuit conductors run between the transfer switch and the generator. One set **shall** be for low voltage control/alarm circuits and the second set for the electrical service. Each set **shall** be installed within its own dedicated conduit/raceway.
- The control/alarm circuits **shall not** be installed within the same conduit or raceway as the electrical service. (See NFPA 70-2005, Article 800.133 for additional information.)
- Conduits/raceways **shall** be sized and routed per the NFPA 70-2005, code (or equivalent in non-domestic installations) and any other applicable national or local codes.
- A dedicated protected electrical circuit **shall** be provided at the generator for engine/battery heaters and service equipment. If located outside, this circuit **shall** have ground fault protection.

6.9.5 INSTALLATION PLAN

Standby generator system installations **shall** be carefully planned and properly installed to ensure proper operation for extended periods. All requirements for the proper location of the generator, properly sized and positioned vents for the required airflow, fuel storage or supply, exhaust system placement and electrical connections **shall** be reviewed by a qualified engineer or inspector to ensure compliance with applicable NFPA 70-2005, national, state and local codes. In general, the following considerations need to be observed:

- Care **shall** be taken to ensure that exhaust gas discharged from the exhaust system **shall** disperse into the open atmosphere and will not be blown or drawn into the building interior. Proper precautions **shall** be taken when generators are installed within or in close proximity to occupied structures.
- Foundation size **shall** be determined based on the geographic area where the system is being installed.
- Door sizes, as existing in the finished structure, **shall** be considered to allow removal/replacement of the largest generator subassembly from within the structure.
- Rain hoods over intake and exhausting vents **shall** be designed to accommodate local extreme environments. Where the potential of high snowfall or drifting is possible, the vent hood **shall** be placed at an appropriate level and directed away from the elements.

NOTE: On radiator cooled generators, cooling air inlet **shall** be at least 1½ times larger than radiator duct receptacle area. Flow of cooling air and heated air should be controlled by automatically operated louvers.

- Earthquake prone areas (Moment Magnitude rating 3 or greater) may require special design and installation features, especially in the area of fuel lines, fuel storage, exhaust system and muffler supports. Appropriate geological information should be consulted regarding seismic considerations.
- For indoor installations, ensure that maximum floor loading will not be exceeded. Shock mounts are recommended and may be required on some installations to minimize vibration transfer.
- Batteries not required for operation of the generator **shall not** be located within a room containing a generator unless the room is properly ventilated.
- Manufacturer's guidelines and specifications to ensure proper air exchange for the generator room **shall** be followed.

6.9.6 ALARMS, METERS AND GAUGES

NOTE: Consideration **shall** be given to assure that remote alarm reporting systems are independent of the power systems they monitor. The reporting system **shall** be such that if the phone line breaks, the primary power source fails, or the common battery bank depletes, then alarms will still be transported.

- All generators **shall** be equipped with an engine high temperature alarm/shutdown and low oil pressure alarm/shutdown.
- All generators **shall** be equipped with an oil pressure gauge.
- Frequency, Voltage and Amp meters are also recommended and should be installed either at the generator control panel or at the transfer switch.
- Additional meter, gauge, remote alarm, engine and battery heater options and needs **shall** be considered. These alarms, if monitored, can provide an early warning to impending problems, thereby reducing cost and down time significantly.

6.9.7 GENERATOR INSTALLATION GROUNDING

All generators, fuel storage tanks above or at grade level, and fences discussed within this chapter **shall** be grounded as described below.

6.9.7.1 INDOOR GENERATOR GROUNDING

Generator systems located indoors **shall** be bonded to the internal grounding system as follows:

- Using the intended chassis grounding connection on the generator, the generator **shall** be bonded to the internal Master Ground Bus Bar in accordance with methods specified in Chapter 5, “Internal Grounding (Earthing).”
- A transfer switch (if not part of the generator unit) **shall** be bonded to the interior Master Ground Bus Bar in accordance with methods specified in Chapter 5, “Internal Grounding (Earthing).”

6.9.7.2 OUTDOOR GENERATOR GROUNDING

Generator systems located outdoors **shall** be bonded to the external grounding system as follows:

- Using the intended chassis grounding connection on the generator, the generator **shall** be bonded to the external site Ground Ring in accordance with methods specified in Chapter 4, “External Grounding (Earthing).”
- If a metallic fuel tank is utilized, the fuel tank **shall** be bonded to the external site Ground Ring in accordance with methods specified in Chapter 4, “External Grounding (Earthing).”
- Metallic fencing surrounding the generator installation **shall** be bonded to the external site Ground Ring in accordance with methods specified in Chapter 4, “External Grounding (Earthing).”
- A transfer switch (if not part of the generator unit) is typically installed in the site building or shelter and collocated with the site electrical service panel. In this case, the transfer switch **shall** be bonded to the interior Master Ground Bus Bar in accordance with methods specified in Chapter 5, “Internal Grounding (Earthing).”

6.9.8 GENERATOR INSTALLATION

The generator system **shall** be installed using all manufacturer's recommended installation practices. In general, observe the following considerations:

- In outdoor installations all foundations **shall** be of proper size to support the load (check local codes for special considerations).
- The generator, fuel tank(s), transfer switch/control panel and all associated components **shall** be securely fastened to the intended foundations.
- Fuel lines **shall** be adequately secured, protected and free of leaks.
- All parts of the system **shall** be installed in such a manner that it **shall** be easily serviceable without undue safety risk while the equipment is operational.
- Installations in earthquake prone areas (Moment Magnitude rating 3 or greater) may require additional fuel, exhaust system and muffler supports. Manufacturer recommendations and local codes **shall** be followed in these areas.
- In earthquake prone areas (Moment Magnitude rating 3 or greater), it is recommended that standby generators be installed on vibration isolators, with flexible cables used for electrical and grounding, and flexible tubing be provided for fuel systems.

6.9.9 GENERATOR STARTUP

Most generators ship without oil and coolant. Many times fuel lines are not connected. An authorized manufacturer's service representative should be used to review the installation, prepare and start the generator. Observe the following considerations:

- All fluid levels **shall** be checked to ensure adequate supply prior to actual startup.
- The generator **shall** be checked for proper voltage and frequency while operating with and without load. These **shall** be within manufacturer's specifications or no greater than a 3% variation from rated voltages and 5% overall variation from specified frequency.
- Setting of all controls within the transfer switch/control panel **shall** be verified and checked to ensure proper load pickup, transfer, re-transfer and shut down.
- The charge rate of the battery charger should be checked.
- The exercise clock should be set and proper operation should be verified. The exercise clock **shall** be set to exercise the generator at a minimum of 30 minutes every 7 days. It is strongly recommended to exercise the generator under full load.
- All alarm connections **shall** be verified and functions tested.
- The fuel system and exhaust system **shall** be checked to ensure there are no leaks.
- Check to ensure that all safety shields and covers are in place.
- If a UPS system is employed in this configuration, tests **shall** be conducted to ensure the UPS functions properly when being fed by the generator. If a problem occurs, frequency and voltage tolerances may need to be reviewed.

6.9.10 GENERATOR SAFETY

In general, the following safety precautions **shall** be observed:

- All moving parts **shall** be enclosed or protected.
- Safety shields and covers **shall** be in place except as necessary for service.
- Hot surfaces such as engine exhaust pipes and mufflers **shall** be protected to ensure that there is no accidental contact by foreign material or persons.
- “No Smoking”, “Caution: Hearing Protection Required”, and “Automatic equipment, may self-start” signs **shall** be posted within a generator room or adjacent to a generator which is located in a room with other equipment.
- Points where exhaust system components pass through walls **shall** have approved feedthrough thimbles installed.
- Fuel lines **shall** be protected from accidental damage.
- Electrical circuits **shall not** be exposed.
- Ensure that exhaust gases disperse and are not drawn back into the interior of the building.
- All manufacturer's safety guidelines **shall** be followed during installation and operation.
- Ensure that generators installed in earthquake prone areas meet all safety requirements for an installation in that area.

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