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MCRP 3-40D.17

ELECTRIC POWER GENERATION AND DISTRIBUTION

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Foreword

This publication has been prepared under our direction for use by our respective commands and other commands as appropriate.

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Preface

ATP 3-34.45/MCRP 3-40D.17 is a compilation of tactics, techniques, and procedures found in doctrine, lessons learned, and other reference material that provides an integrated systematic approach to electric power generation, distribution, and management. It codifies lessons learned over the past 16 years and serves commanders and their staffs as a comprehensive guide for planning, producing, distributing, and managing electrical power in support of military operations.

ATP 3-34.45/MCRP 3-40D.17 is suitable for Army and Marine Corps commanders/leaders and staffs at all echelons. The principal audiences for this manual are engineer staff, officers at brigade/Marine air-ground task force (MAGTF) headquarters and below, and planners who have staff proponency for electrical power generation and distribution. It is also a valuable reference for Army and Marine Corps trainers, educators, combat developers, and other Services.

Commanders, staffs, and subordinates ensure that decisions and actions comply with applicable United States, international, and, in some cases, host-nation laws and regulations. Commanders at all levels ensure that personnel operate in accordance with the law of armed conflict and applicable rules of engagement. (See FM 6-27 and ATP 3-01.15/MCRP 3-25E/NTTP 3-01.8/AFTTP 3-2.31.)

ATP 3-34.45/MCRP 3-40D.17 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and the text. Terms for which ATP 3-34.45/MCRP 3-40D.17 is the proponent (the authority) are italicized in the text and are marked with an asterisk (*) in the glossary. Definitions for which ATP 3-34.45/MCRP 3-40D.17 is the proponent publication are boldfaced in the text. For other definitions shown in the text, the term is italicized, and the number of the proponent publication follows the definition.

ATP 3-34.45/MCRP 3-40D.17 applies to the Active Army, Army National Guard/Army National Guard of the United States, United States Army Reserve, Department of Defense Civilians, deployed contractors, and total force Marine Corps, unless otherwise stated.

The proponent of ATP 3-34.45/MCRP 3-40D.17 is the United States Army Engineer School. The preparing agency is the Maneuver Support Center of Excellence (MSCoE) Fielded Force Integration Directorate (FFID), Doctrine Development Division; Doctrine Branch. Send comments and recommendations on a DA Form 2028 *(Recommended Changes to Publications and Blank Forms)* to Commander, MSCoE, ATTN: ATZT-CDC, 14000 MSCoE Loop, Suite 235, Fort Leonard Wood, Missouri 65473-8929; by e-mail to usarmy.leonardwood.mscoe.mbx.engdoc@mail.mil; or submit an electronic DA Form 2028. The Commanding Officer of the Marine Corps Engineer School is appointed as the manager and author of Marine Corps content in this publication. Marine Corps personnel should submit suggestions and changes by email mces_s3_doctrine_smb@usmc.mil or written correspondence to Marine Corps Engineer School (Attn: S-3/Doctrine), PSC Box 20069, Camp Lejeune, NC 28542-0069.

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Introduction

Modern warfare relies on systems powered by electricity, making electricity an essential element that supports all warfighting functions. Command and control, intelligence, movement and maneuver, fires, sustainment and logistics, and protection/force protection depend on electricity for an array of capabilities ranging from communicating with units in the field to protecting the United States and its allies with strategic missile defense assets. Command and control communications systems within each echelon of command posts are highly reliant on electrical power for everything from issuing orders to maintaining an electrical common operational picture. Commanders rely upon command and control systems to achieve the situational understanding necessary for timely decision making. Reliable electricity powers equally important intelligence systems, administrative processes, medical equipment, sustainment operations, and long-range precision weapons. The result of this growing dependence on electricity is an increase in the quantity and quality of power needed to support military operations. The indispensable nature of electrical power compels commanders and planners to ensure that those needs are met.

From the military perspective, electrical power encompasses the entire spectrum of power generation, distribution, and management that supports military operations. This spectrum consists of tactical power (low-voltage), prime power (medium-voltage), and utility electrical power (commercial or host-nation—low, medium, or high-voltage).

ATP 3-34.45/MCRP 3-40D.17 contains the following five chapters and eight appendixes that provide supplemental material:

- **Chapter 1** describes the role of electrical power in support of military operations and provides an overview of the electrical power source levels (tactical, prime, and utility). The chapter then summarizes the responsibilities of the unit power manager.
- **Chapter 2** is an overview of tactical electrical power systems.
- **Chapter 3** focuses on prime power electrical systems and their role in supplying medium-voltage power to support military operations.
- **Chapter 4** outlines the role of utility power support to military operations.
- **Chapter 5** discusses the planning, resourcing, and construction of power systems and power management.
- **Appendix A** provides information on the capability of Army electrical power units.
- **Appendix B** provides information on the capability of Navy prime power units.
- **Appendix C** provides information on Air Force electrical power capabilities.
- **Appendix D** provides information on Marine Corps electrical power capabilities.
- **Appendix E** discusses the power systems equipment available within the military Services.
- **Appendix F** describes international interoperability including worldwide phases, voltages, plug and outlet configurations, and frequency characteristics.
- **Appendix G** is an overview of the electrical inspection process.
- **Appendix H** provides information on electrical safety on the battlefield regarding electrical shock, arc blast, and grounding.

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Chapter 1

Electrical Power

This chapter discusses electrical power and policy pertaining to electrical power—that is generated, distributed, or managed by the Armed forces of the United States. The Department of Defense (DOD) considers energy used in military operations and in training to support unit readiness for military operations (as operational energy). The term "operational energy" includes energy used by tactical power systems and weapons platforms. Unit power managers recommend the most efficient and tactically appropriate electrical power production and distribution systems necessary to meet the demands for continuous and reliable electrical power.

ELECTRICAL POWER SUPPORT TO MILITARY OPERATIONS

1-1. Military operations require electrical power. Command and control (C2) centers; medical support; communications systems; weapons systems; and other mission-related functions, facilities, and equipment require electricity. Sources of power range from batteries to mobile power sources to local commercial power. The demands for electricity steadily increase throughout the duration of an operation. DOD uses standard and nonstandard electrical power sources and distribution to provide the electrical power needed for military operations. Commanders are responsible for ensuring adequate power to meet operational needs.

ELECTRICAL POWER SUPPORT ACROSS THE COMPETITION CONTINUUM

1-2. During large-scale combat operations, military units execute a combination of offensive, defensive, and stability tasks to defeat an enemy and establish conditions that achieve the commander's desired end state. These operations involve the synchronization of many simultaneous unit actions. Aggressive execution, mobility, and surprise are the most effective means for achieving the tactical success of offensive and defensive tasks. Contemporary operational environments require the reliability and capability electrical power. At the onset of combat operations, when the operating tempo is high, units typically rely on organic low-voltage power capabilities to meet the electrical requirements for executing offensive, defensive, and stability tasks. As offensive and defensive operations shift to stability, the transition from tactical electrical power to prime electrical power enables commanders to reduce or consolidate power-related resources and/or logistical requirements.

ELECTRICAL POWER SUPPORT TO DEFENSE SUPPORT OF CIVIL AUTHORITIES

1-3. Military forces support civil authorities at federal and state levels by performing defense support of civil authorities (DSCA) tasks. U.S. federal military forces, DOD civilians, contract personnel, National Guard forces, and other component assets provide support when assistance is requested from civil authorities for domestic emergencies, law enforcement activities and other domestic activities of qualifying entities with special events under the DSCA mission (see ADP 3-28 and DOD Dictionary of Military and Associated Terms). DSCA includes tasks that address the consequences of natural or man-made disasters, accidents, terrorist attacks, and incidents in the United States and its territories. Military forces conduct DSCA tasks only after civil authorities have requested assistance and the Secretary of Defense has authorized the deployment of military personnel to provide the level of assistance requested. DSCA actions are always subordinate to civilian authority control. For additional information on DSCA, see ATP 3-28.1/MCRP 3-30.6/NTTP 3-57.2/AFTTP 3-2.67/CGTTP 3-57.1, and MCTP 3-03A.

Electrical Power Support to the National Response Framework

1-4. The United States Army Corps of Engineers (USACE) manages components of the national public works infrastructure. This management includes national waterways maintenance, environmental remediation and recovery operations, real estate, disaster recovery operations, and general project management functions. USACE is the primary agency for the National Response Framework Emergency Support Function (ESF) #3, Public Works and Engineering. In this role, the Corps of Engineers assists the Department of Homeland Security and the Federal Emergency Management Agency by coordinating federal public works and engineering-related support and providing technical assistance, engineering expertise, and construction management to prevent, prepare for, respond to, or recover from domestic incidents.

1-5. Temporary emergency power is one of the missions within ESF #3. This temporary emergency power support ranges from technical expertise and assistance through the complete management of an emergency power mission (including procurement, installation, operation, and generator maintenance). Some of the technical expertise and assistance tasks include—

- Assessing conditions and capabilities of existing emergency generation equipment.
- Assessing damaged electrical distribution systems and equipment.
- Assessing emergency power requirements needed at a facility.
- Ensuring that all emergency and/or hazard power planning is conducted.
- Ensuring that safety inspections of electrical distribution systems and equipment are conducted.
- Installing, operating, fueling, and maintaining the emergency power generation equipment.
- Troubleshooting, repairing, and operating emergency generation and distribution equipment.

1-6. The planning and execution of this temporary emergency power requirement involve the combined efforts of several partners, to include DOD military units that are trained and equipped to perform tasks at medium and low levels of voltage. DOD assigns the ESF #3 temporary power mission to specially trained units.

Electrical Power Support to Foreign Humanitarian Assistance

1-7. Foreign humanitarian assistance refers to those Department of Defense activities conducted outside the United States and its territories to directly relieve or reduce human suffering, disease, hunger, or privation. The U.S. military normally conducts foreign humanitarian assistance operations, including foreign disaster relief operations, to alleviate the suffering of foreign disaster victims, in support of another U.S. government department or agency. The U.S. military also conducts foreign humanitarian assistance activities in various steady-state programs to support geographic combatant commander security cooperation programs or to achieve specific theater campaign plan objectives.

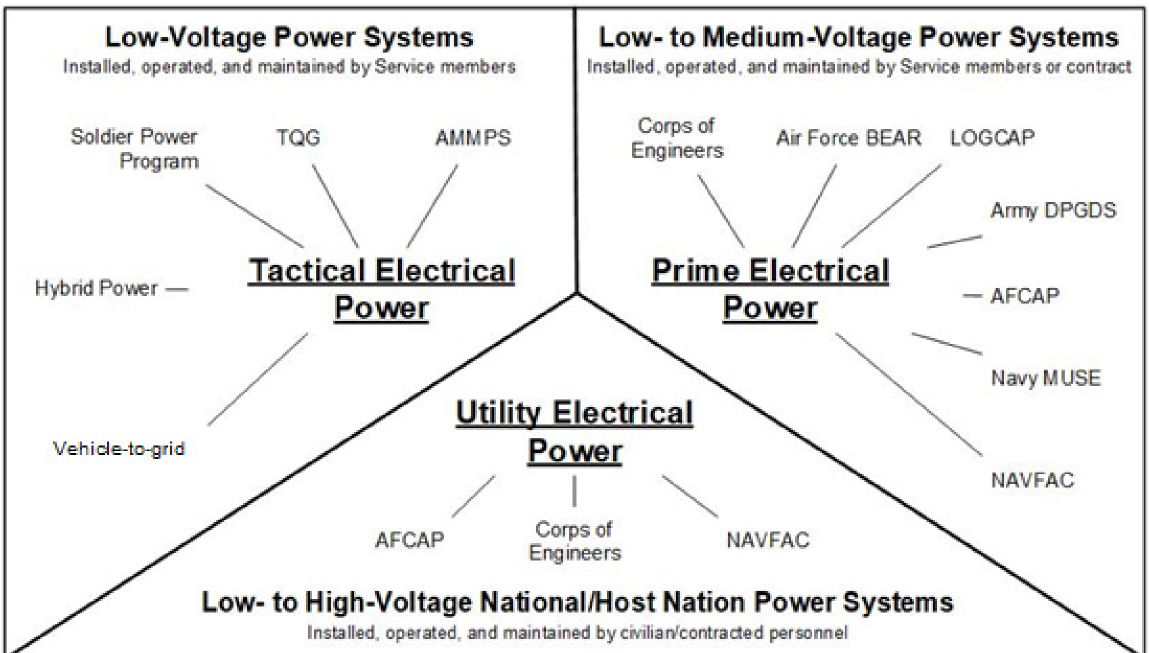
1-8. Foreign humanitarian assistance typically involves a greater number of engineering tasks and equipment. The level of assistance required can vary from limited, highly specialized teams to an entire engineer unit. Specialized engineering teams are used to assess damage or estimate engineering repairs, and they can assist in support roles (such as emergency electrical power supply and distribution, utilities repair work, water purification, and well-drilling operations). During large-scale foreign humanitarian assistance operations, engineer units can provide essential general engineering support (including facility construction, structural repair, and base camp construction) for deployed forces. These forces request military support (including engineering support), which should be initiated and coordinated through the lead federal agency.

OPERATIONAL ENERGY

1-9. Operational energy is a critical enabler for a range of military operational capabilities from the Service member to strategic levels. The Operational Energy Innovation Office of the Secretary of Defense focuses on three primary areas of operational energy development: 1) powering the force, 2) electrifying the battlespace, and 3) commanding energy. Operational energy drives effectiveness through mobility, agility, flexibility, resilience, and sustainability. An effective strategy balances combat effectiveness and the efficiency of energy consumption, distribution, and production through energy-informed decisions. To be successful, operational energy strategies are embedded into leadership, planning, acquisition, training, behaviors, and execution. These strategies include designing energy-efficiency into equipment, considering energy requirements during operational planning, and managing energy conservation practices used by individuals and organizations. The informed use of energy enhances effectiveness, reach, mobility, agility, and sustainability; reduces risk to personnel; and lessens logistics-related disruptions.

POWER SYSTEM ARCHITECTURE

1-10. The selection of an electrical power system for a given application is based on a trade-off among technical necessities, power requirements, and duration of use. The aim of determining which type of system will be used is to achieve optimum performance, ease of maintenance, and a high degree of safety. Figure 1-1 depicts the power system architecture, showing representative capabilities in each operational space.



AFCAP	Air Force Contract Augmentation Program
AMMPS	Advanced Medium Mobile Power Source
BEAR	base expeditionary airfield resources
DPGDS	Deployable Power Generation and Distribution System
LOGCAP	Logistics Civil Augmentation Program
MUSE	mobile utilities support equipment
NAVFAC	Naval Facilities Engineering Command
TQG	tactical quiet generator

Figure 1-1. Power system architecture

ELECTRICAL POWER SOURCE LEVELS

1-11. The electrical engineering community defines a watt as a measurement of electrical power, a volt as a measurement of potential electrical energy, and an ampere as a measurement of electrical current flow. The prefix "kilo-" may be added to these units to indicate multiplication by 1,000; for example, one kilowatt (kW) equals 1,000 watts. It is useful for planners to think of these terms as they would water within a pipe system. An ampere moving through an electrical conductor is similar to the water moving through a pipe. Voltage is similar to the pressure of water in the pipe. An electrical planner should think of voltage as being how far a system sends power and the kW as how much power the system consumes. Another clear distinction that electrical engineers make with regard to an electrical system is between the kW and kW-hour. The kW is a measure of the actual electrical load or the demand, while the kW-hour is a measure of energy consumption. A power system should provide enough power for all electrical loads in the system to meet the system demand.

1-12. Electrical power sources range from batteries and tactical generator sets to large prime power systems and complex national utility grids. Individual power (included in tactical power) is the lowest tactical-power level and is generally limited to batteries and small-unit power sources (less than 1 kW). Tactical power includes unit organic sources up to 500 kW with low voltage outputs of 600 volts (VAC) and below. Prime power is composed of sources with medium-voltage outputs of 601 VAC to 69 kilovolts from standard and nonstandard sources. Utility power systems are civilian-managed or contractor-managed and -provided. Each source varies in complexity, efficiency, and reliability but ultimately provides the user with electricity for mission needs. Table 1-1 shows the correlations used between each capacity, unit responsibility, and voltage. The expected durations are guidelines derived from ATP 3-37.10/MCRP 3-40D.13 and JP 3-34 for planning purposes.

Table 1-1. Electrical power source levels

Power Level	*Soldier Power Program (including individual)*	*Tactical Power*	*Prime Power*	*Utility*
Source output	≤ 1 kilowatt	≤ 500 kilowatts	> 500 kilowatts	Nation-dependent
Distribution	≤ 120 volts alternating current ≤ 24 volts direct current	Up to 600 volts (low-voltage)	601 volts–69,000 volts (medium-voltage)	Up to 230,000 volts (low- to high-voltage)
Expected Duration	Organic	Initial (including organic) (up to 6 months)	Temporary or Semipermanent (up to 10 years)	Enduring
Responsibility	Unit (Unit Power Manager)	Unit (Unit Power Manager)	249th Engineer Battalion, U.S. Navy Mobile Utilities Support Equipment, Prime Base Expeditionary Engineering Force, Contract	U.S. Army Corps of Engineers contract

Tactical Electrical Power

1-13. During the initial phase of operations, units typically use organic tactical electrical power systems to meet electrical power needs. Tactical electrical power systems have limited capacity and distribution, but those systems provide greater mobility. Also, tactical electrical power systems include individually-carried power sources (batteries and renewable power supplies) and low-voltage generators. Tactical power systems are typically standardized systems that are sized to meet unit requirements. Operational planners should anticipate that power requirements will change over time and address new energy requirements within the operational plan. Adding more power production capacity is usually necessary to meet the demand. At other times, efficiencies are gained by consolidating unit power sources into a microgrid. (See chapter 5 for information about the planning of electrical power and transitions between the levels of power).

1-14. The advantages of consolidated power generation and distribution include (see chapter 2 for tactical electrical power consolidation planning)—

- Consolidated security of power generation assets.
- Improved power system reliability.
- Increased cost efficiency per kW-hour.
- Reduced fuel demands.
- Reduced wear on equipment not designed for long-term, continuous operations.
- Streamlined maintenance.

1-15. Tactical electrical power is produced and distributed for user voltage and is installed, operated, and maintained by units. Tactical electrical power sources include individual power, generators, alternative and renewable sources of energy, fuel cells, hybrid power, and stored electrical power.

1-16. Individual power is the lowest level of tactical power, and it is derived from a variety of sources. These power sources supply electricity for operating individually worn or carried equipment. Individual power is provided by batteries, fuel cells, small solar-photovoltaic panels, and lightweight portable generator sets.

1-17. The next level of tactical electrical power is from mobile power sets organic to units. DOD developed a standard family of electrical power sources and distribution equipment for providing tactical electrical power. This standard family is listed in MIL-STD-633G.

1-18. Transitioning to a prime or utility power source level is typically triggered by time, capacity, or events. Engineer prime power units provide technical support, expertise, and voltage transformation for supporting military operations and base camps.

Prime Electrical Power

1-19. Prime power sources consist of low- to medium-voltage generators rated for providing continuous, reliable power. Prime power sources use transformers to step down from a medium voltage to a lower voltage for equipment use. Military prime power systems are installed, operated, and maintained by personnel trained in prime power or are provided through a sustained contract solution. Medium-voltage systems can generate and distributing power through several miles of distribution lines. Prime power is typically employed for supporting multiple units along with critical infrastructure but can also be employed for powering a single large demand system (such as a radar). This power is provided on an as-needed basis to support operations, as directed by the theater army or joint task force commander. Installing prime power systems is appropriate when it is not practical to use tactical generators or when utility power is not available or is unstable.

1-20. As the situation changes, a commander may direct the transition to longer-term solutions. The responsibility for operational control, sustainment, and maintenance of the existing power system is transferred to civilian, contracted, or host-nation personnel. Life cycle equipment replacement and further expansion of the power requirement create a site-specific power system that is typically composed of fixed, commercial generators and electrical equipment (or utility power, if available).

Utility Electrical Power

1-21. The output capacity of utility electrical power varies from a few megawatts to several gigawatts, transmitted over medium-voltage and high-voltage distribution and transmission lines, that are then transformed to low voltages for user equipment. Utility power is an option if it is reliable enough to suit the unit needs in an area of operations and if it is compatible with mission equipment. Utility power is normally distributed at the operational level through a civilian power grid. The sophistication and reliability of these systems vary widely across the globe. Personnel who are qualified to work with medium-voltage systems make connections to commercial distribution networks, pending coordination and approval. Connections can also be made by coordinating with the local utility company. Once connected, the system provides continuous power service that is virtually maintenance-free. A contract or host-nation support agreement is required when operating on a utility power grid.

Power Source Level Transitions

1-22. Considerations are given to the location, duration, and end state of power requirements during operational planning. Included in this planning is the potential transition between electrical power source levels. The objective of transitioning power levels is to reduce the logistical burden.

1-23. There is no one-size-fits-all solution to supplying electrical power across the competition continuum. The capacity, mobility, and flexibility requirements of the electrical system for a C2 node during major combat operations are very different from those of a base camp or logistics hub. A site occupied at the cessation of combat operations typically develops into an enduring location as the phases of an operation change.

1-24. Figure 1-2 depicts a typical base camp power life cycle, and figure 1-3 depicts an example of electrical power system transitions. Power systems are employed in a scalable fashion to use minimal resources when supporting changing electrical power demands. A power system typically begins with an organic tactical power system; transitions to the military and/or contracted prime power system; and then ultimately transitions to a sustained power system operated and maintained by civilian personnel or a contractor, possibly including local utility power, for enduring locations. These transitions can occur consecutively or concurrently. The goal is to employ power systems that support and build on one another while meeting mission requirements. See chapter 5 for additional information. For more information on base camp power, see ATP 3-37.10/MCRP 3-40D.13.

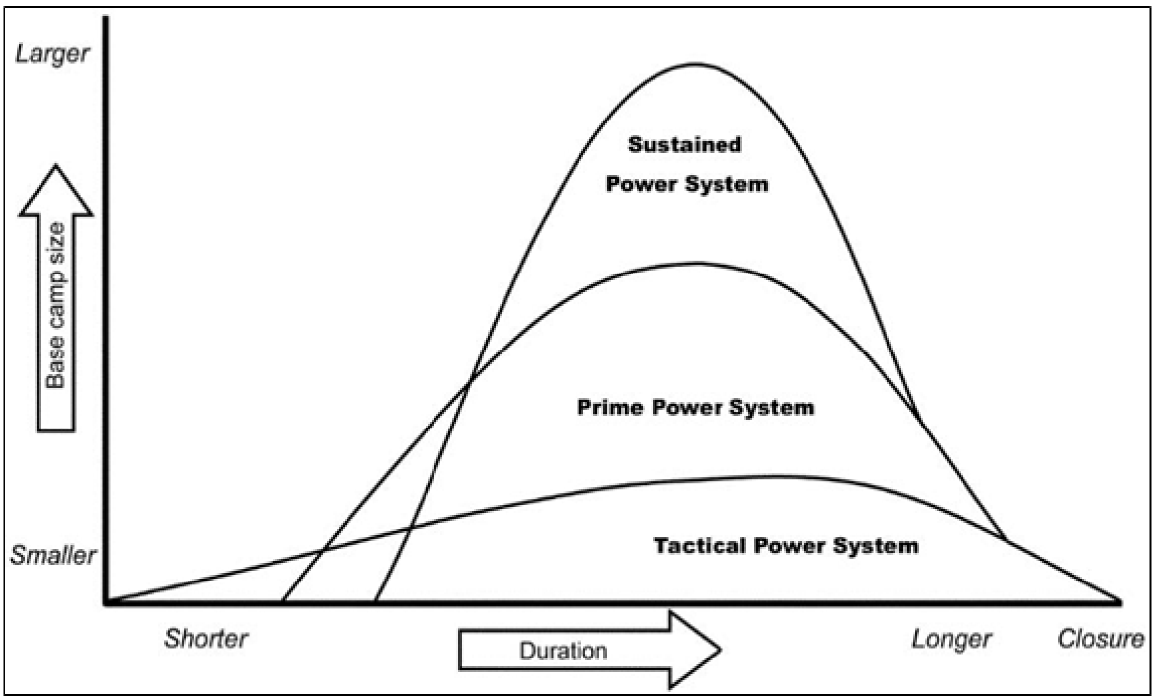
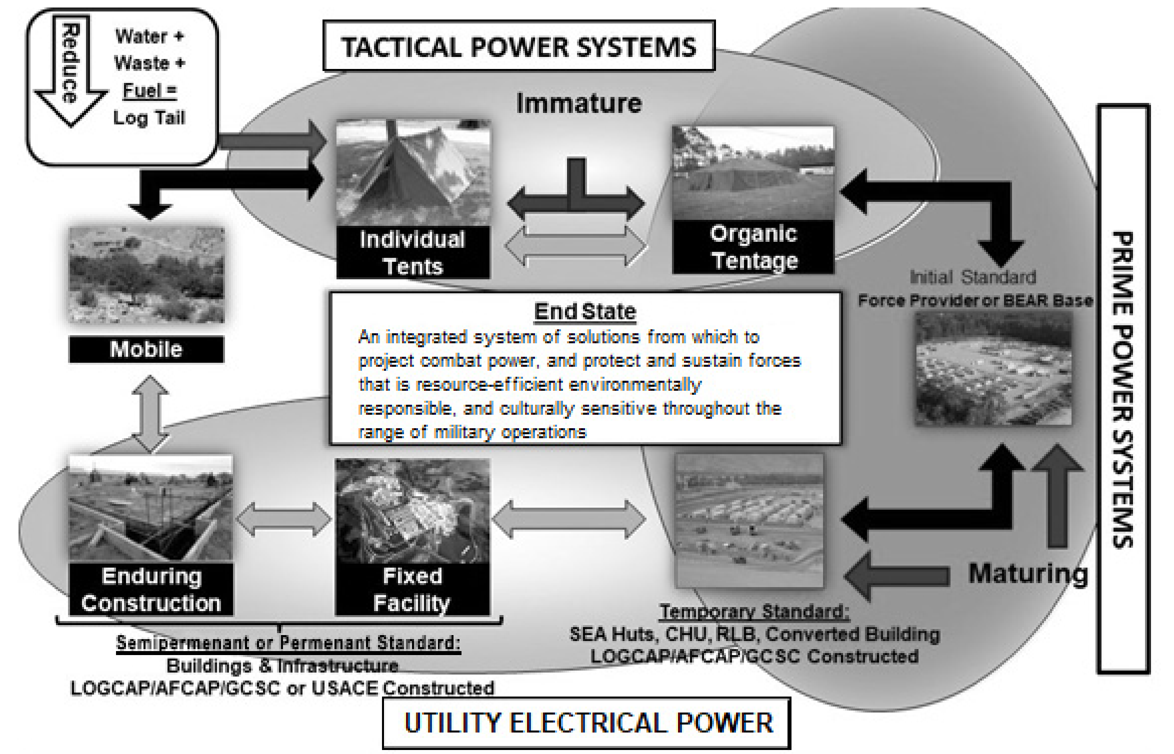


Figure 1-2. Base camp power life cycle



Legend:

AFCAP	Air Force Contract Augmentation Program
BEAR	base expeditionary airfield resources
CHU	containerized housing unit
GCSC	global contracting support contract
Log	logistics
LOGCAP	Logistics Civil Augmentation Program (Army)
RLB	relocatable building
SEA Huts	Southeast Asia Housing unit, timber
USACE	U.S. Army Corps of Engineers

Figure 1-3. Electrical power transitions

UNIT POWER MANAGEMENT RESPONSIBILITIES

1-25. Power managers should be appointed at each echelon from the battalion level and up to assist commanders with effective and efficient power management. Unit power managers should have a military occupational specialty (MOS) related to electrical power generation, distribution, and installation. Unit power managers should be familiar with organic power generation and distribution equipment and be familiar with the equipment possessed by attachments assigned to their units. During the planning phase, power managers ensure that the organic power assets are employed in the most efficient manner for satisfying unit power and mission requirements. Units employ microgrids to achieve the most efficient use of organic tactical generators by increasing reliability through redundant power sources, increasing fuel efficiency and decreasing maintenance requirements by using the fewest number of generators required by the load, and avoiding wet stacking. See section 2-11 for more information on wet stacking. For more details on Service power capabilities and MOSs, see appendixes A through E.

1-26. As the electrical power system transitions from tactical to prime or utility power, power management responsibilities may be transitioned to a supporting organization. For example, during the life cycle of an Army base camp, the number of tenant units and the camp population may increase. This can cause the responsibility for power management to transition from multiple unit power managers to a military prime power unit via direction given by the theater army engineer organization. Under these circumstances, the prime power unit ensures that the base camp power generation and distribution system is expanded to address the current and estimated future demand. Some base camps may be designated to transition from military prime power management to contract power plants and distribution systems. The military prime power unit retains responsibility for power management throughout the prime power and utility levels of base camp development. Subject matter experts (SMEs) from USACE and military prime power units aid the theater engineer staff officer in designing and installing power grids for maximizing the generation and distribution of operational energy across one or more base camps.

1-27. The key components to effective power management include the power demand assessment, power source selection and placement, and power distribution layout. The power demand assessment (load assessment) produces a list of all equipment needing power, the total amount of power required by that equipment, and the priority/criticality level of that equipment. The assessment should help determine the selection and placement of power sources. Power distribution layout refers to the location of all equipment is located in relation to the power source and the distribution equipment required for connecting equipment to the power source. Table 1-2 outlines elements of power management that power managers should consider.

Table 1-2. Elements of power management

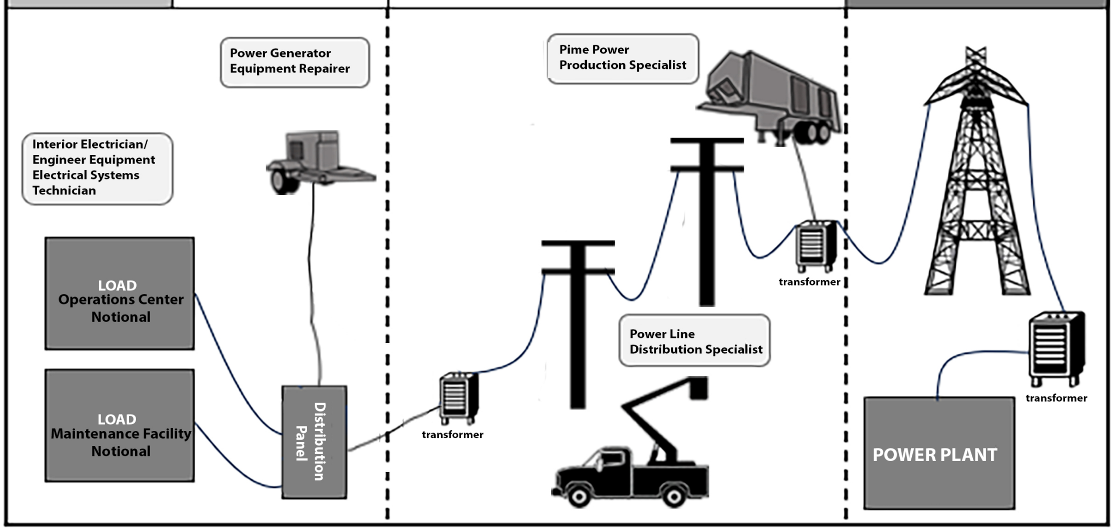
• Analyze Requirements: Gather mission information and define the requirement. • Plan: Develop a concept based on requirements, considering command priorities. • Select: Choose equipment based on availability, affordability, and suitability. • Design: Develop a physical layout of equipment based on physical parameters. • Procure: Purchase, order, or select equipment.	• Employ/Construct: Move, lay out, and connect equipment. • Operate: Start and stop equipment based on varying requirements. • Sustain: Refuel, inspect, and maintain fluid levels for continued operation. • Maintain: Periodic ally service and repair. • Recover: Disconnect, service, repair, and repackage equipment for future missions.

Authority With Jurisdiction

1-28. The authority that has jurisdiction over electrical matters is the organization, office, or individual responsible for approving the equipment and materials needed for an installation or procedure, as required by United Facilities Criteria 3-560-01. The authority—typically at the theater level—possesses technical expertise and knowledge about electrical systems, applicable codes, and standards. The safety officer determines and establishes the requirements of the code or standard to be used for approving equipment, materials, installation, procedures, and associated safety training and standards. Electrical safety trainings and definitions must comply with AR 385-10 or MCO 5100.29B. The authority may assign (in writing) delegates to act on its behalf when deployed. Delegates work closely with the safety officer to ensure that users will be able to understand electrical safety requirements.

1-29. Individuals receive training that delineates the responsibilities for the generation and distribution of electrical power. Figure 1-4 depicts a general capability delineation between the MOSs and of the three levels of power.

	Low Voltage •Interior Wiring •Tactical Generators •Micro-grids	Medium Voltage •Power Grids •Commercial Generators	High, Extra High, Ultra High-Voltage •Distribution Lines •Power Plants
Distribution	≤ 600 volts	600 volts–69,000 volts	69,000–230,000 volts
Typical Responsibility	Unit Power Manager	249th Engineer Battalion, U.S. Navy Mobile Utilities Support Equipment, RED HORSE, Prime Base Expeditionary Engineering Force, Contract	Not a service competency
Military Occupation Specialty (MOS)	12R, 91D, 1141, and 1142	12P, 12Q, and ASI U4	



Legend:

ASI	additional skill qualifier
RED HORSE	rapid engineer deployable heavy operational repair squadron engineer
U.S.	United States

Figure 1-4. Power distribution responsibilities

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Chapter 2

Tactical Electrical Power

This chapter discusses the tactical electrical power system requirements that are prevalent during all phases of military operations. During the initial phases of an operation, units rely on organic tactical electrical power assets for mission-essential electrical power. DOD standard mobile electricity-power-generating equipment can be rapidly deployed, produces low-voltage electricity, and does not require the use of transformers.

ELECTRICAL POWER SUPPORT ACROSS THE COMPETITION CONTINUUM

2-1. Large-scale combat operations against a peer threat are demanding in terms of operational tempo and lethality. Mobility, surprise, and aggressive execution are the most effective means for achieving tactical success. Since mobility is a primary consideration during the offense and defense, tactical electrical power meets the unit electrical power requirements while offering the most flexibility to the commander. Electrical service for the tactical end user may also be provided by existing low-voltage electrical systems in utilities infrastructure (see appendix F for more information). These services decrease the logistics burden by reducing the runtime of power generation equipment and aid in concealment by reducing the tactical equipment footprint.

2-2. Enemy use of measurement and signature intelligence collection assets must be considered when placing and operating tactical power-generating systems. Tactical generators emit electromagnetic, visual, auditory, and infrared signatures that can be easily detected. The closer together the systems are, the larger the collective signature becomes. However, the distance between tactical power sources and user equipment should not exceed approximately 91 meters (300 feet). Tactical dispersion, camouflage, and concealment can reduce the signature of tactical generators while improving the survivability of the unit using the generators. See chapter 5 for information about electrical power planning and see ATP 3-37.34/MCTP 3-34C for more information regarding camouflage and concealment.

TACTICAL ELECTRICAL POWER MANAGEMENT

2-3. Unit commanders determine how tactical electrical power that is needed to support operations is prioritized and employed. The staff assists in planning and resourcing tactical electrical power support. The unit power manager can assist the staff by coordinating for technical expertise as needed and for the equipment necessary to maintain reliable/continuous electrical power. In addition, tactical electrical power generation and distribution responsibilities are dependent on unit organic personnel and the power manager.

UNIT POWER MANAGER

2-4. The unit power manager represents the commander when managing the unit tactical electrical power-generating and distribution assets. As the unit tactical electrical power planning expert, this individual knows the electrical demand and the general capabilities of the unit organic power equipment. The unit tactical electrical power planning expert might not have an extensive knowledge of each system, but this individual is responsible for planning, employing, and managing resources to meet mission demands.

2-5. The unit power manager has two main tasks:

- Ensure power generation assets are being employed as effectively as possible to meet mission requirements.
- Maintain an ideal electrical power source-to-demand relationship. The optimal load for tactical generators is 80–100 percent rated capacity to avoid wet stacking. (For more information on wet stacking, see Section 2-11.)

TACTICAL ELECTRICAL POWER EQUIPMENT OPERATOR

2-6. Commanders are responsible for ensuring that personnel assigned to the unit are trained and licensed tactical electrical power system operators. Licensed personnel operate assigned equipment according to the operator instructions contained in technical manuals. Other sources of information that can be used to help ensure that critical equipment receives the electricity required for operation include this publication and the related publications listed in the reference section of this publication. Operators are also responsible for operator level preventive maintenance checks and services. Trained and licensed operators are key for every electrical power generation and distribution system.

TACTICAL POWER GENERATION EQUIPMENT SPECIALIST

2-7. Units that are assigned tactical electrical power systems have access to power production maintainers. These individuals are usually assigned to the unit; however, they sometimes reside in a supporting maintenance unit. Army MOS 91D and United States Marine Corps MOS 1141 personnel are capable of interpreting an Automated Distribution Illumination System, Electrical (AutoDISE) diagram and laying out the power generation and distribution equipment.

2-8. MOS 91D skill level 3 and MOS 1141 2,000-level-event-qualified personnel are trained on AutoDISE planning software. These individuals are also the unit organic tactical power experts. Commanders should direct the unit MOS 91D and MOS 1141 to train operators and assist unit leaders in drafting electrical power generation and distribution plans or request that supporting MOS 91D and MOS 1141 do so.

TACTICAL ELECTRICAL POWER GENERATION AND DISTRIBUTION SYSTEMS

2-9. Electrical power generation equipment converts fossil fuels to electricity. Electricity is also produced from nuclear, geothermal, solar, wind, hydroelectric, hydrogen, and biomass sources. These power systems come in a variety of forms—from single source (spot generation) to multiple source (microgrid or hybrid)—and, with the right resources, are highly configurable for meeting the needs of any mission.

2-10. A tactical power system distributes electricity from the generator to the end user. A tactical power system has two main subsystems: generation (the power source) and distribution (boxes and cabling connecting the source to the end user). A single power source that delivers electricity directly to single or multiple loads is commonly called "spot generator"; multiple power sources that can be synchronized to deliver electricity to multiple loads through a distribution network are commonly called "microgrids." Microgrids create efficiencies through multiple generators being connected to a distribution network as generators are offline when not required.

2-11. During power production, a unit power manager is tasked to prevent mechanical problems by meeting mission requirements and maintaining an ideal electrical power source-to-demand relationship. Continuously operating tactical generators to support relatively light demand loads (less than 30 percent of the generator output rating) can cause a condition called "wet stacking." Wet stacking develops when an engine is continuously operated below its optimal temperature rating, regardless. A low engine temperature allows lubricating oil to enter the cylinders, which prevents fuel from burning completely. Corrective-maintenance actions due to wet stacking include frequently cleaning blocked fuel injectors and replacing damaged internal engine components. Excessive soot buildup and the presence of a black, oily fluid around the exhaust of the generator are telltale signs of wet stacking.

TACTICAL MOBILE ELECTRICAL POWER SOURCES

2-12. The DOD standard family of tactical mobile electrical power sources includes skid-mounted generator sets and trailer-mounted power units or power plants. The size (kW rating), features (skid-mounted versus trailer-mounted), accessories (winterization kit), and quantity of generators match requirements driven by the operational environment, mission variables, and unit capabilities. In addition, the emplacement of generators in proximity to the anticipated load is considered.

TACTICAL POWER DISTRIBUTION SYSTEMS

2-13. Power distribution systems subdivide and distribute electricity from power sources to multiple users. These systems are portable, surface-laid, plug-and-play, and intuitively employable by end users with minimal tool requirements. The systems easily configure to user needs. Power distribution includes all boxes, panels, cabling, power receptacles, and lighting. They are designed to distribute electrical power for distances up to approximately 91 meters (300 feet) from the source to the user equipment (receptacle, lights, and environmental-control unit). Greater distances can increase voltage drops to unacceptable levels and adversely affect the performance of power-consuming equipment. For more information on voltage drop, see TC 9-60 and TM 3-34.46/MCRP 3-40D.11.

2-14. As with selecting a generator, the operational environment, mission variables, and unit capabilities are considered when designing and purchasing distribution equipment. Distribution systems are designed to fit and take full advantage of the source size. For example, the output of a 60-kW generator under normal conditions is 160–200 amperes. Therefore, a 60-kW generator should be paired with an M200 (200 ampere) distribution box with 200 ampere cabling. Anything less would not allow the full capacity of the generator to be utilized.

TACTICAL ELECTRICAL POWER PRODUCTION AND DISTRIBUTION LAYOUTS

2-15. Figures 2-1, page 2-4, and 2-2, page 2-5, illustrate common tactical electrical power employment layouts. Although each layout meets power needs, some layouts are more economical and operate more efficiently than others. For example, an assembly area or base camp may contain multiple types of distribution layouts. The layouts can also evolve over time from spot generation, to microgrid and power plant, to utility grids. The primary goal when designing a tactical electrical power layout is to satisfy the mission-essential power needs while improving efficiency, which reduces logistical requirements. ATP 3-37.10/MCRP 3-40D.13 contains additional planning factors for determining tactical electrical power requirements for base camps.

2-16. Spot generation configuration makes use of generator set connected to single or multiple loads. Any setup where all power generation assets must be run to meet the load demand is considered spot generation. For example, a unit that uses a power plant composed of two generator sets is employing spot generation. There are many instances for which spot generation is the most suitable power distribution option—a radar site in a remote location, for example. Another example is a shop van and shelters with a variety of mission equipment connected to a single source through load cables and a distribution center. Some of the advantages of spot generation include the simplicity of the system, the expeditious setup and tear-down, and the requirement of fewer resources. Some of the disadvantages include a lack of scalability; a lack of power production consolidation requiring more resources for fueling and maintenance; a tendency to underload generator sets (causing wet stacking), and a loss of power during generator maintenance.

2-17. Figure 2-1 (A) shows the simplest option—a generator set connected directly to the load without any power distribution equipment beyond the directly attached cable. Figure 2-1 (B) depicts a distribution center (M40) that is connected to multiple loads. Figure 2-1 (C) illustrates an electrical feeder system (M100) powering multiple distribution centers to connect additional loads. For more examples of spot generation layouts, see TM 9-6150-226-13.

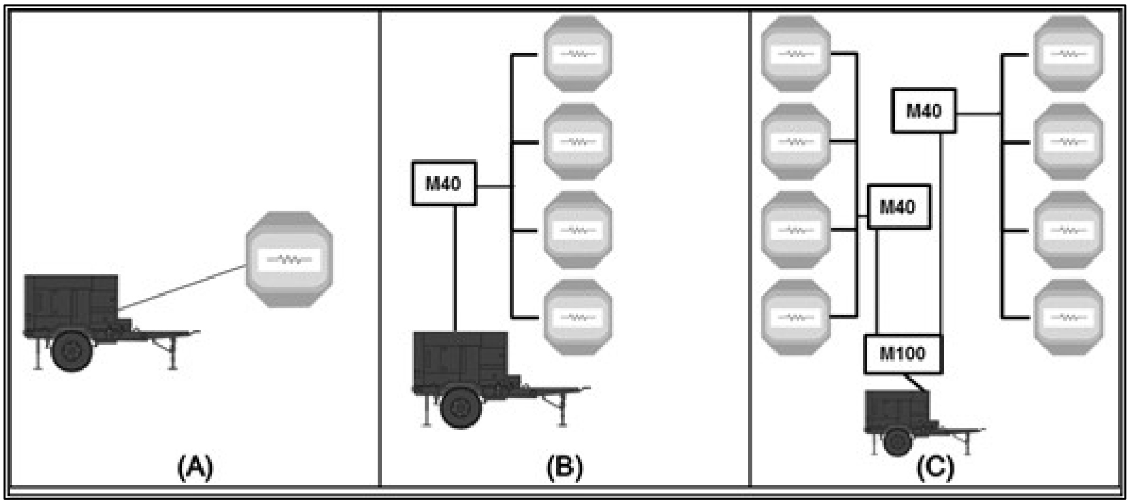
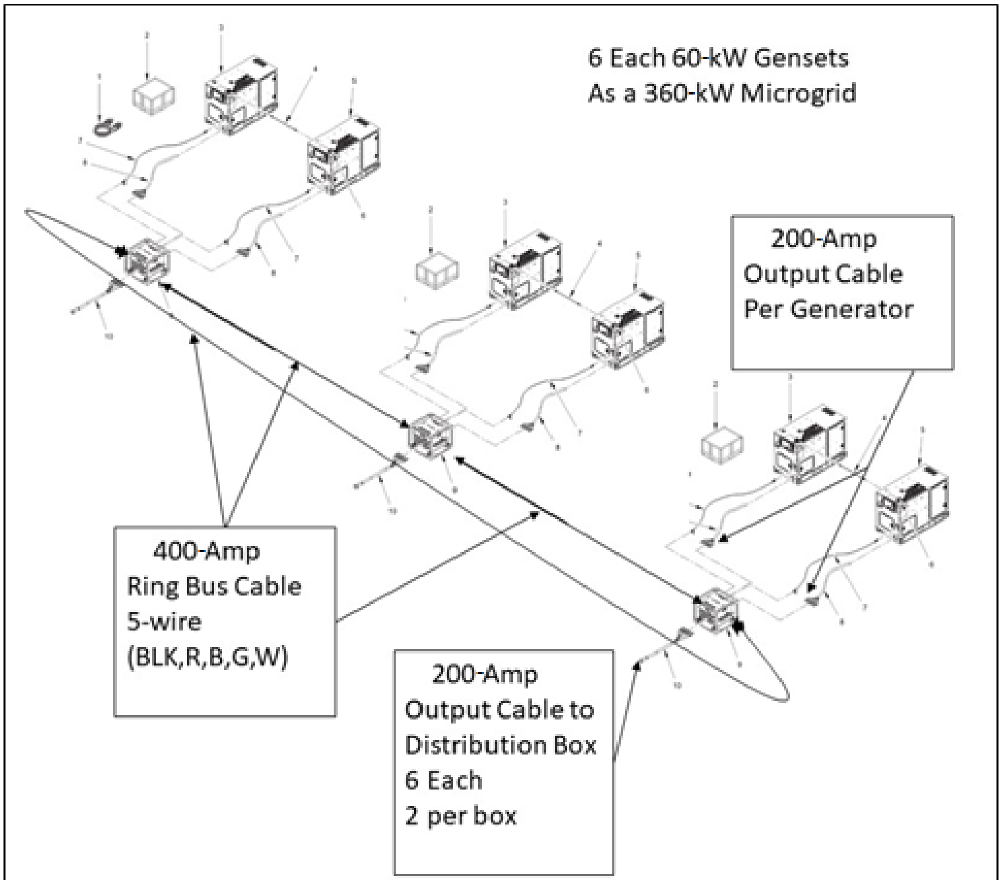


Figure 2-1. Spot generation

2-18. Tactical microgrids make use of unit organic power production and distribution equipment. Using the Advanced Medium Mobile Power Source (AMMPS) to establish a tactical microgrid system. As an example, the microgrid control function and control panel are on the generator set. Based on demand, the microgrid automatically controls when generators start and stop. Tactical microgrids consist of multiple power sources connected to electrical feeder systems that distribute power to multiple loads through distribution centers.

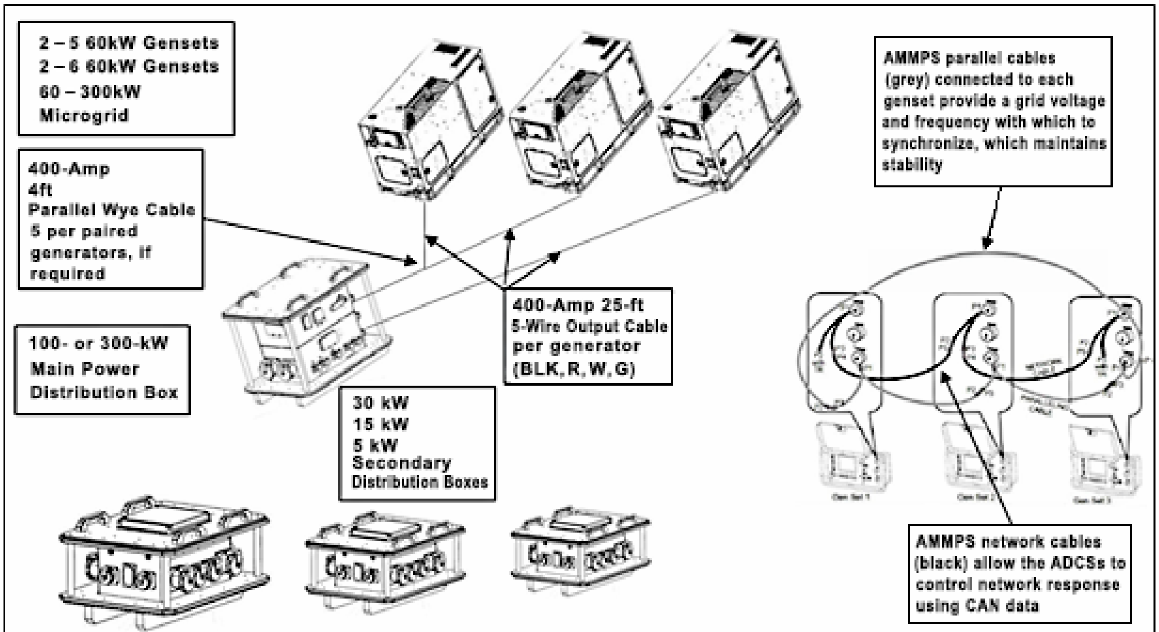
2-19. Some considerations for microgrids include that they require longer setup times, additional equipment than what's required for spot generation, and expertise during design and setup to avoid surpassing the acceptable voltage drop distance. In addition, enhanced grids are more highly efficient for fueling and maintenance operations; have increased capacity; are highly scalable (the AMMPS can connect to a total of six 60-kW generators); allow for redundancy so that power is not lost during maintenance of generators; and provide easy transition to a sustained power system, as the mission dictates. Figure 2-2 provides an example of an Army design for a tactical microgrid. Figure 2-3, page 2-6, provides an example of the Marine Corps design.



Legend:

Amp	ampere	kW	kilowatt
B	blue	R	red
BLK	black	W	white
G	green		

Figure 2-2. Example of Army tactical microgrid



Legend:

ADCS	advanced distribution control system	ft	foot
AMMPS	Advanced Medium Mobile Power Source	G	green
Amp	ampere	Gensets	generator sets
B	blue	kW	kilowatt
BLK	black	R	red
CAN	controller area network	W	white

Figure 2-3. Example of Marine Corps design for tactical microgrid

ALTERNATIVE POWER SOURCES

2-20. Alternative and renewable power sources are obtained by harvesting energy from the environment (solar, thermal, wind, and water), converting it to an electrical output for immediate use, or storing it in a rechargeable battery system for later use. The main advantage of these power source alternatives lies in reducing external requirements for fossil fuels. Depending on the mission variables and given suitable environmental conditions, these power sources can supplement or replace conventional generator sets. Principal applications might include tactical radio power, force protection, and surveillance systems, and communications-electronics battery charging. A common example of an alternative power source is solar-photovoltaic panels connected to a storage battery system through a controller. Matched with generator sets, an alternative energy source enables users to reduce fuel needs for power generation. An example of an alternate power source is the Marine Corps Solar Portable Alternative Communications Energy System (SPACES). SPACES is a lightweight, portable, renewable-energy system designed to provide power for platoon and squad size units operating in remote locations. Marines use SPACES to recharge batteries that power communications equipment (such as satellite communications radios), reducing the number of batteries carried on extended patrols. Figure 2-4 contains a photograph and technical details for SPACES. For more details on the Marine Corps power equipment, see TM 11300-15/1.

TAMCN: A04242G	I.D.: 12411A	NSN: 5985-01-619-6212

Functional Description

SPACES is a lightweight, portable, renewable energy system designed to provide power for platoon and squad size units operating in remote locations. SPACES manages up to 400 watts of power generated from lightweight, durable solar panels and provides a regulated 24 VDC output to energize battery-operated weapon systems. SPACES is fielded with an expanded assortment of components and enhanced charging profiles to increase battery-charging efficiencies. SPACES II can energize man-packed and handheld tactical radios and laptop computers, charge multiple battery types, and convert 24 VDC to 115 VAC for limited AC power requirements.

Technical Description

Information		**Dimensions**	
Manufacturer:	Iris Technology	Length (in):	22.75
Model:	78535-103399	Width (in):	15.0
Power		Height (in):	8.0
Input		Weight (lbs):	26.0
DC Solar Panel:	2 x @ 12 VDC	ft^2/ ft^3	2.4/1.6
Vehicle DC:	9 to 33 VDC	**Temperatures**	
Output		Operating:	-4°F to +131°F
DC:	12-32 VDC	Storage:	-59°F to +160°F
AC:	115 VAC		

Replaced TAMCN: H00112G, SPACES.

Associated TAMCNs: A01297G, THHR AN/PRC-152 (V)1; A03367G, Radio Set AN/PRC-117G (V)2; A20447G, Radio Set (MARITIME) AN/PRC-148 (V)3 (C); A20687G, Radio Set (Falcon II) AN/PRC-117F (V)1C; A20797G, Radio Set AN/PRC119F.

Transportability: Treat as cargo.

Legend:

AC	alternating current	NSN	national stock number
AN/PRC	Army Navy/Portable Radio Communications	SPACES	Solar Portable Alternative Communication Energy System
DC	direct current	TAMCN	table of authorized material control nuber
F	Fahrenheit		
ft	feet	THHR	tactical handheld radio
I.D.	item designator	VAC	volts, alternating current
in	inches	VDC	volts, direct current
lbs	pounds		

Figure 2-4. SPACES

2-21. Planners should consider leveraging renewable energy-based power sources (solar, waste-to-energy, and wind) once circumstances make these options viable for improving sustainability. The proper employment of energy alternatives requires foresight during the planning stages. Plans should include considerations for regional solar insolation, wind patterns, and terrain features (mountains, vegetation, buildings). Allowing for these features during the planning process is important because the features can block, attenuate, or interfere with available solar and wind resources. Also, allocating enough space for renewable energy systems is another essential consideration for their employment. Figure 2-5 depicts the site layouts for two alternative power sources.

Figure 2-5. Alternative power source setups

Fuel Cells

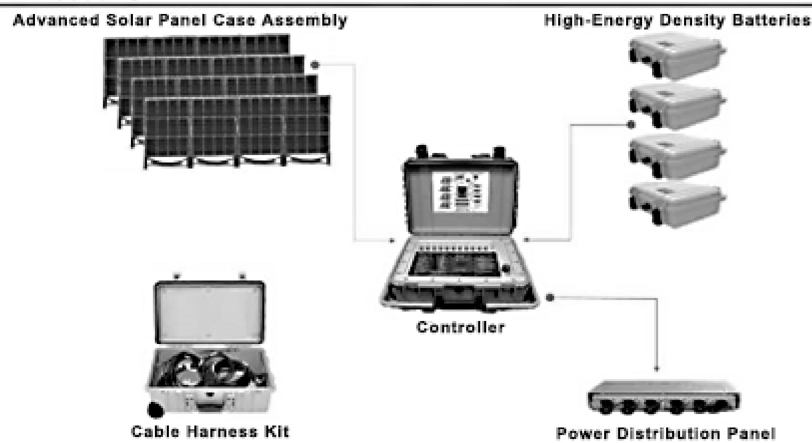
2-22. Fuel cells chemically convert fuel to electricity through a noncombustion process that is similar to that of batteries. However, the chemical energy of batteries is self-contained, while fuel cells require an external fuel source to sustain the chemical reaction. Consequently, fuel cells produce electricity for as long as fuel is supplied, while batteries must be recharged. Fuel cells are more energy-dense than batteries and are potentially more energy-efficient than conventionally-fueled power sources. They are essentially silent and release little to no harmful emissions.

Hybrid Power Systems

2-23. Hybrid power systems combine multiple power sources with energy storage ability to control the distribution of electricity. Hybrid power systems require a generator that can provide the power required for an average rated load. In addition to the generator, including other power sources (such as alternative and renewable power sources) can increase efficiency. An example is a generator set combined with a battery system. During periods of low demand, the battery can supply power to the load. The system automatically starts the generator when the load has discharged the battery to a certain threshold. A key benefit of hybrid power systems is the reduction of fuel needed for power production compared to the continuous operation of a generator at low loads. Hybrid power systems are designed to operate with an individual generator and/or with multiple generators configured into a microgrid.

2-24. One critical planning factor for a load is the center mission profile. Constant loads that are close to the power system capacity do not benefit from a hybrid source. It is also necessary to consider maintenance tasks, environmental limitations, and safety factors for the batteries in the energy storage system. Figure 2-6 contains photographs and technical details for the Ground Renewable Expeditionary Energy System (GREENS). GREENS is a hybrid power system used by the Marine Corps. It is a portable power generation system that incorporates solar panels, energy storage, the one-man portable generator, and alternating current (AC)/direct current (DC) power sources. GREENS provides an average continuous output of 300 watts of electricity—enough to power a Marine Corps battalion combat operations center. Marines also use GREENS to power High-Mobility Artillery Rocket Systems and M777 howitzers, eliminating the need to tow a 3-kW generator and reducing vehicle idle time. Figure 2-7, page 2-10, depicts the one-man portable generator, a lightweight portable generator that is used exclusively with the GREENS for providing auxiliary power. It produces 120 volts/60 hertz AC electricity. Nominal power output for the one-man portable generator is 800 watts, while peak output is 1,000 watts. It has an internal fuel tank and can be augmented with an extended run tank. The one-man portable generator operates on liquid fuel (jet propulsion-8, F-24, or F-34).

TAMCN: B00507G | **I.D.: 12115B** | **NSN: 6117-01-618-5094**



Functional Description

GREENS consists of modular, man-transportable components that, when assembled into a system, accept energy from many different sources, distribute the energy using an intelligent management system, and store excess energy to provide an average continuous output of 300 watts (nominal) or 1,000 watts (peak). GREENS uses lithium ion iron phosphate high-energy density batteries (HEDBs) for energy storage. GREENS provides units with a renewable source of power to energize essential ground communications an targeting systems at locations isolated from main routes of supply.

Technical Description

Information		**Dimensions**	
Manufacturer:	UEC Electronics	**Controller**	
Model:	0754A20-001	Length (in):	16.0
Power		Width (in):	21.2
Input		Height (in):	8.3
Solar Panel:	4 AISPCA @ 40–70 VDC	Weight (lb):	51.0
DC Vehicle:	18–32 VDC	ft^2/ ft^3	2.4/1.6
AC:	85–220 VAC @ 50/60 Hz	Temperature:	-4°F to 131°F
Output		**HEDB (Qty 4)**	
DC:	22–30 VDC	Length (in):	16.5
Regulated DC:	28 VDC	Width (in):	14.0
Total System Weight (lbs)	200	Height (in):	7.0
		Weight (lb):	40.0
		ft^2/ ft^3	1.6/0.9
		Temperature:	-2°F to 131°F

Legend:

ADCS	advanced distribution control system	in	inches
AISPCA	advanced integrated solar panel case assembly	lb	pounds
ft	feet	NSN	national stock number
GREENS	Ground Renewable Expeditionary Energy System	Qty	quantity
HEDB	high energy density battery	TAMCN	table of authorized material control number
Hz	hertz	VAC	volts, alternating current
I.D.	item designator	VDC	volts, direct current

Figure 2-6. GREENS

TAMCN: B01427B	I.D.: 12590A	NSN: 6115-01-647-6849

Functional Description

The 1MPG is a 1-kW lightweight portable generator. The 1MPG provides 1-kW AC power to support load requirements. The internal fuel tank of the 1MPG can be augmented with an XRT, allowing up to 72-plus hours of continuous operation.

Technical Description

Information		**Dimensions**	
Manufacturer:	INI Power Systems Inc.	**Generator Set**	
Model:	1KW FLEX FUEL GE	Length (in):	17.7
Power		Width (in):	14.5
Output		Height (in):	15.0
Generator Output:	120 V	Weight (lb):	31.0
Temperatures		ft^2/ ft^3	1.8/2.2
Operating:	-4°F to +122°F		
Storage:	-40°F to +176°F		

Transportability: Treat as cargo.

Legend:

AC	alternating current	NSN	national stock number
F	Fahrenheit	TAMCN	table of authorized material control number
I.D.	item designator		
in	inches	V	volts
lbs	pounds	XRT	Extended Run Task
1MPG	one-man portable generator		

Figure 2-7. One-Man Portable Generator

ELECTRICAL POWER STORAGE

2-25. Power may be generated in several ways—ranging from generator sets to renewable energy-based power sources. A basic problem in power production is that when a generating source produces power, the load must use the power at that time or the power is wasted; therefore, a means to store energy for later use is required to increase efficiency. Energy storage may be in the form of batteries, pumped hydro, flywheels, chemical reactions, or heat (molten salts). Energy storage systems are not just for routine storage but can serve as vital backups and life-saving sources of energy in times of stress when no other sources are working. Without proper energy storage, renewable and other energy systems could become unstable or, at times, even unworkable. Energy storage systems range from individual, rechargeable batteries to larger utility scale storage systems used within a power grid. Microgrid configurations may include energy storage (see figure 2-8).

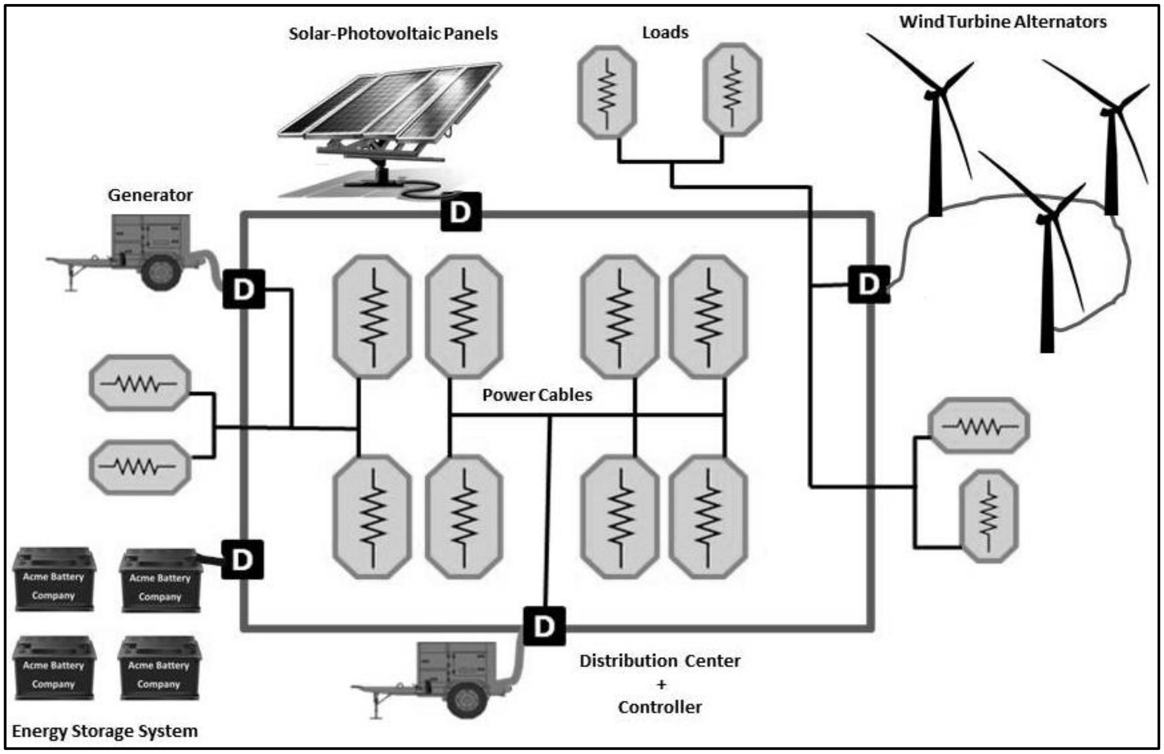


Figure 2-8. Example of future tactical microgrid

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Chapter 3

Prime Electrical Power

This chapter focuses on prime electrical power—a capability that provides continuous, reliable, commercial-grade, and medium-voltage power to support military operations. Prime electrical power is typically used to support critical infrastructure and fixed facilities when utility power is unavailable or where tactical power is impractical. The prime power capability is closely integrated and synchronized with the overall general engineering plan for the theater of operations. A primary benefit of medium-voltage prime power systems is the capability to distribute electricity over longer distances and larger areas than tactical generators.

PRIME POWER

3-1. Prime power consists of a centralized power plant and a medium-voltage distribution network that provide continuous and reliable power. Transformers are used to convert power from medium voltage to user-level voltages and are installed, operated, and maintained by prime-power-qualified personnel or through a contract. Prime power systems can be organic, nonorganic, or a combination.

3-2. Prime power systems are typically employed when there is a stand-alone requirement for commercial-grade utility power due to operations. They are a requirement for supporting critical facilities or large base camps in forward areas. This level of power is provided as needed to support military operations when they are being directed by the theater or joint force commander (see ATP 3-37.10/MCRP 3-40D13 and JP 4-04 for further discussion on theater basing strategies). Military prime power units generate electrical power; provide advice and technical assistance on all aspects of electrical power and distribution systems; and are capable of designing, analyzing, surveying, and constructing a prime power system.

3-3. Base camps with expanded and enhanced capabilities sometimes call for prime power generation. The transition from tactical generation to prime power generation typically saves on costs and improves fuel-use efficiency. Modular base camp life support sets—such as Force Provider and Harvest Falcon—include an organic generation capability that is sufficient for their internal components that are designed for a specific number of occupants. Reliable prime power generation should be used, when possible, with the appropriate amount of backup power generation available for critical facilities, when needed.

PRIME POWER MANAGEMENT

3-4. The commander's representative for managing prime power systems is the prime power manager. The prime power manager works with unit power managers and is linked to the base operating support integrator (BOS-I) for matters of prime power use. The prime power manager knows the capabilities of the prime power equipment and assesses the electrical demand. Prime power management involves planning, designing, installing, employing, maintaining, and managing power resources to meet mission demands. The engineering staff section of a joint staff cell typically has a prime power SME to aid the theater engineer in the coordination of prime power capabilities.

PRIME POWER PERSONNEL

3-5. Military prime power personnel are specially trained in their MOS for operating and maintaining prime power generation and distribution equipment. Military prime power personnel may also provide contracting officer technical representative oversight for contracted prime power.

3-6. Prime power personnel perform electrical safety inspections but do not usually perform interior, low-voltage electrical work (such as installation of electrical fixtures or receptacles). These functions should be performed by licensed contracted electricians or interior electricians with MOS 12R/1141.

PRIME POWER ELECTRICAL GENERATION

3-7. Prime power is uninterrupted electrical power that is continuously produced at a centralized power plant. Generators require periodic maintenance and service to avoid breakdowns. To obtain a continuous source of prime power, multiple synchronized generators are installed in parallel. This arrangement allows maintenance to be performed on one or more generators while the others produce power. The same principle is used in the production of utility power and tactical generator microgrids.

3-8. Prime power generation is scalable to meet mission requirements of 500 kW and higher. (See appendix E for a description of prime power system capabilities and capacities.) The prime power plant layout consists of areas for generation, fuel storage, primary switching, distribution, and transformation and a control center. The plant requires allotted spaces for petroleum, oil, and lubricant products, distribution equipment storage, and a maintenance area.

PRIME POWER DISTRIBUTION

3-9. Prime power-qualified personnel install power distribution networks to meet mission needs above tactical power capability and capacity, per AR 385-10. The following paragraphs discuss the two parts of a medium-voltage distribution system: primary (medium voltage) and secondary (user voltage).

PRIMARY DISTRIBUTION

3-10. Primary distribution systems carry medium-voltage power from the power plant to the transformers or secondary distribution centers (SDCs). Primary distribution systems can be surface-laid, installed overhead, directly buried, or ducted underground. Surface-laid primary distribution is the initial distribution format used because that format can be quickly installed and removed. Surface-laid distribution is a temporary distribution format that is typically replaced with direct burial or overhead distribution once mission allows. Direct-burial distribution makes use of primary switching centers, pad-mounted transformers, or SDCs and direct-buried cables. The direct-buried cable is constructed with an armored, shielded power cable that is also suitable as surface-laid cable. Overhead distribution makes use of utility poles; aluminum, steel-reinforced conductors; air switches; pole-mounted transformers; and pad-mounted transformers. The power-planning process discussed in chapter 5 provides planning considerations for selecting distribution methods and equipment. Appendix E provides specific equipment information for the Deployable Power Generation and Distribution System.

3-11. Beyond the power plant, the components of the primary distribution system are the—

- **Switchgear.** An electrical-power switchgear enables the consolidation of power source inputs and the distribution to various output feeders and branch circuits. The primary switchgear for the Deployable Power Generation and Distribution System is called the primary switching center. See appendix E for information on the primary switching center.
- **Transformer.** Transformers are used for changing voltages in an electrical distribution system. For example, a transformer could have an input of 4,160 VAC and then output 120/208 VAC. The correct transformer for an electrical distribution system output is the correct voltage level for the electrical loads in that system. Different parts of the world generate and distribute power at different levels of frequency and voltage. See appendix F for international interoperability. The transformer for the deployable power generation and distribution system is the SDC.
- **Cables.** Cables are how power systems transmit electricity. These cables may be commonly referred to as conductors, lines, wires, or feeders in the distribution system. Power cables are rated by their manufacturer to carry certain voltage and amperage levels; this rating is taken into consideration when designing a distribution system.

3-12. Distribution systems can be configured in one of the following layouts:

- **Radial layout.** The radial layout is the simplest, least expensive, and quickest layout to install. In this layout, power is transmitted along a single path from the source to each electrical load. An electrical fault in the distribution system causes the termination of power to all loads past the fault. Figures 3-1 and 3-2, page 3-4, illustrate a radial distribution system under normal and fault conditions.

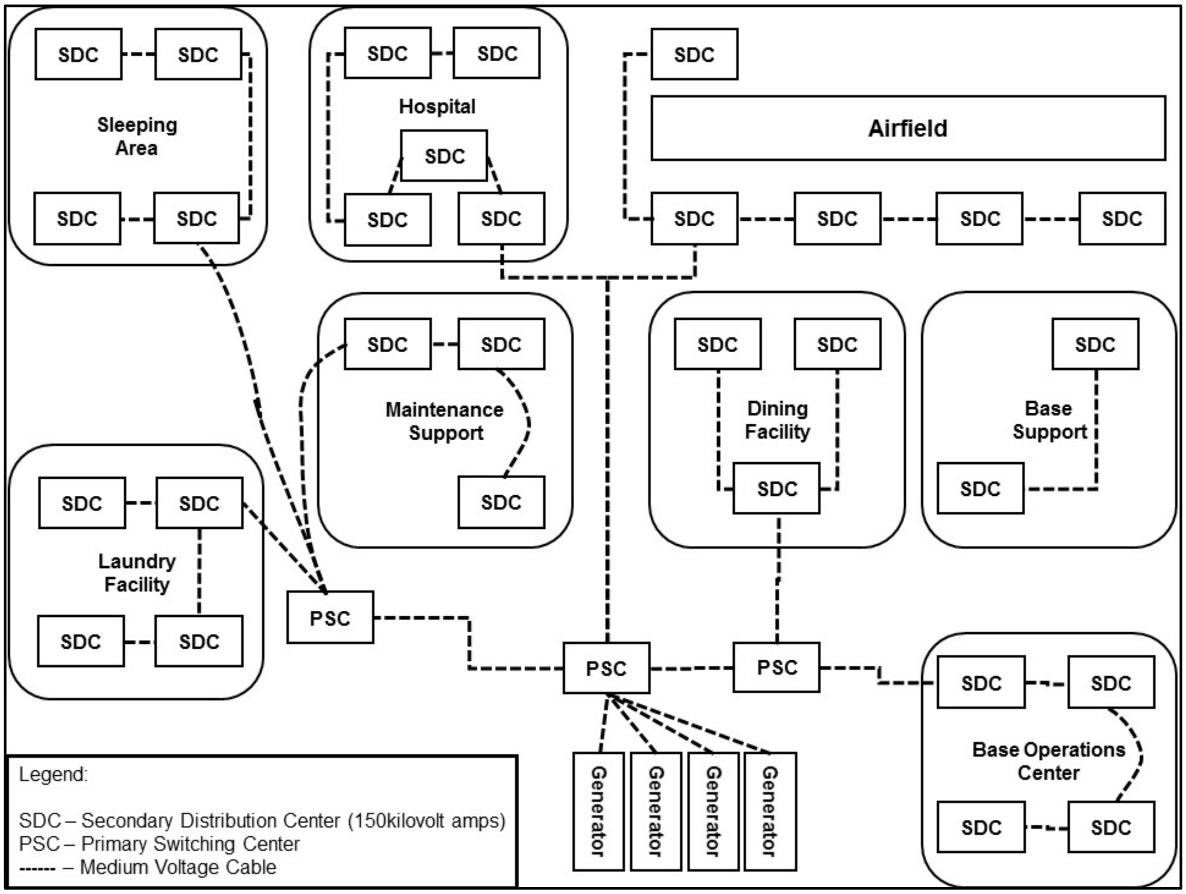


Figure 3-1. Example of a radial layout—normal

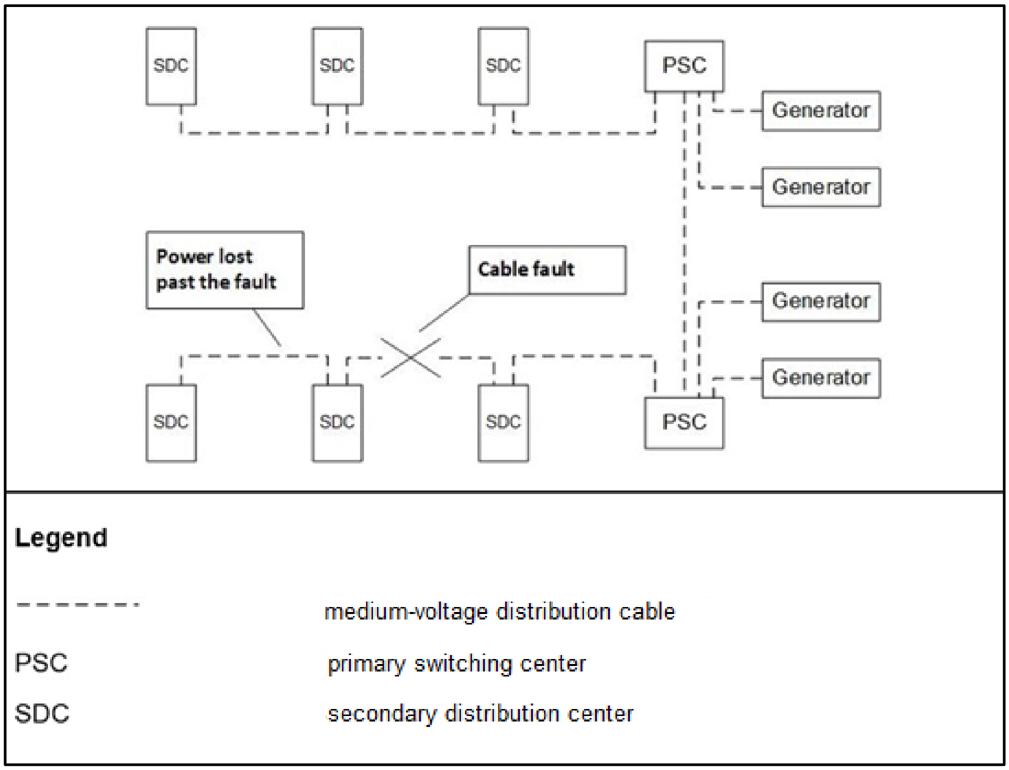
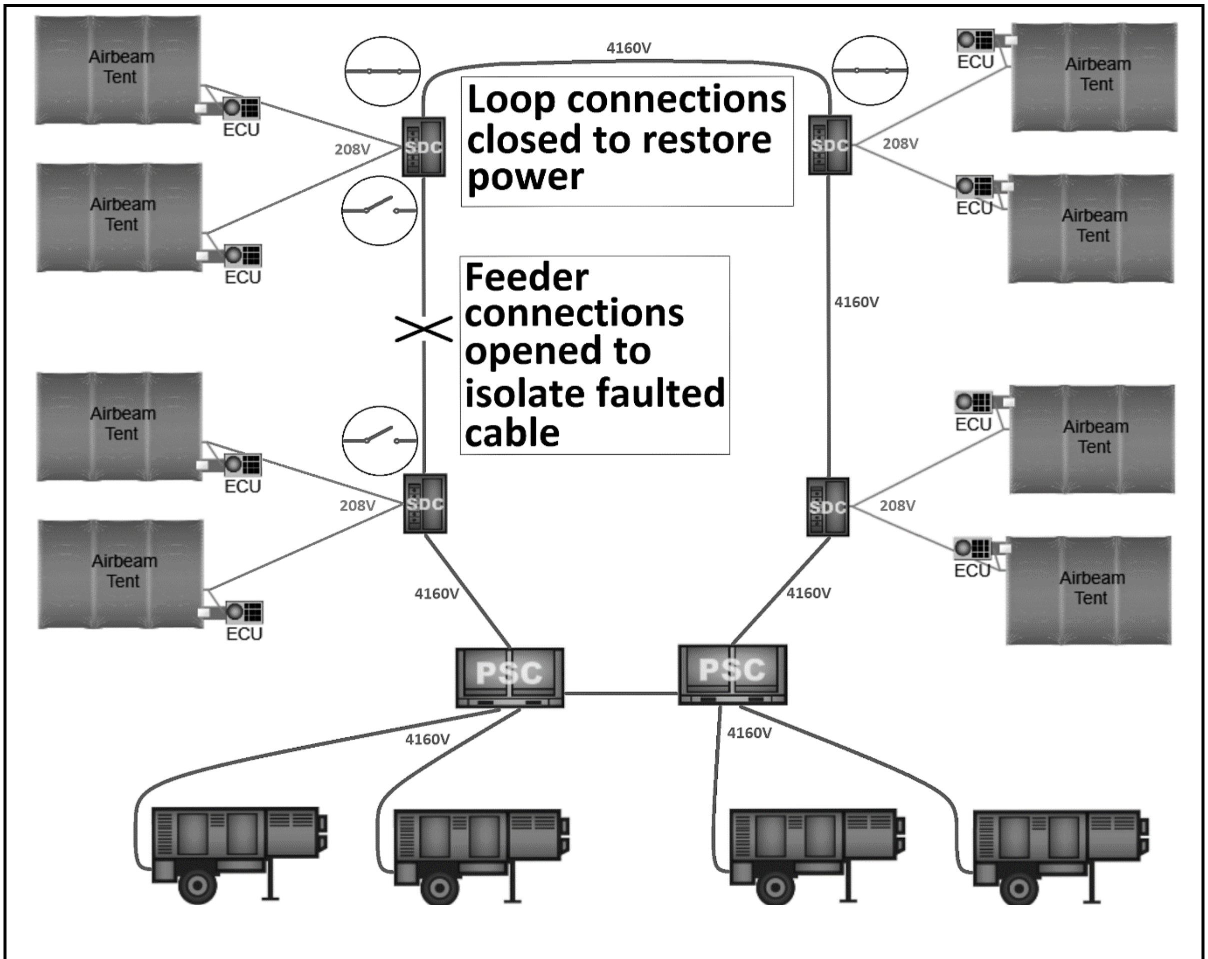


Figure 3-2. Example of a radial layout—fault

- **Loop.** A loop (also called a ring) power distribution layout—as the name implies—loops through the service area and returns to the original point. The looped feeder is usually tied into an alternate power source. Switches placed in strategic locations allow the system to be configured to supply power to the customer from either direction (or power source). If one source of power fails or a feeder cable is damaged, switches are automatically or manually opened and closed, and power is fed to customers from the other source. The loop layout provides more reliable service than the radial layout, with only short interruptions during switching. The loop is more complex and expensive than radial systems because more switches and conductors are required, but the improved system that results is more operationally resilient and reliable. Figure 3-3 illustrates a loop distribution layout under faulted condition.

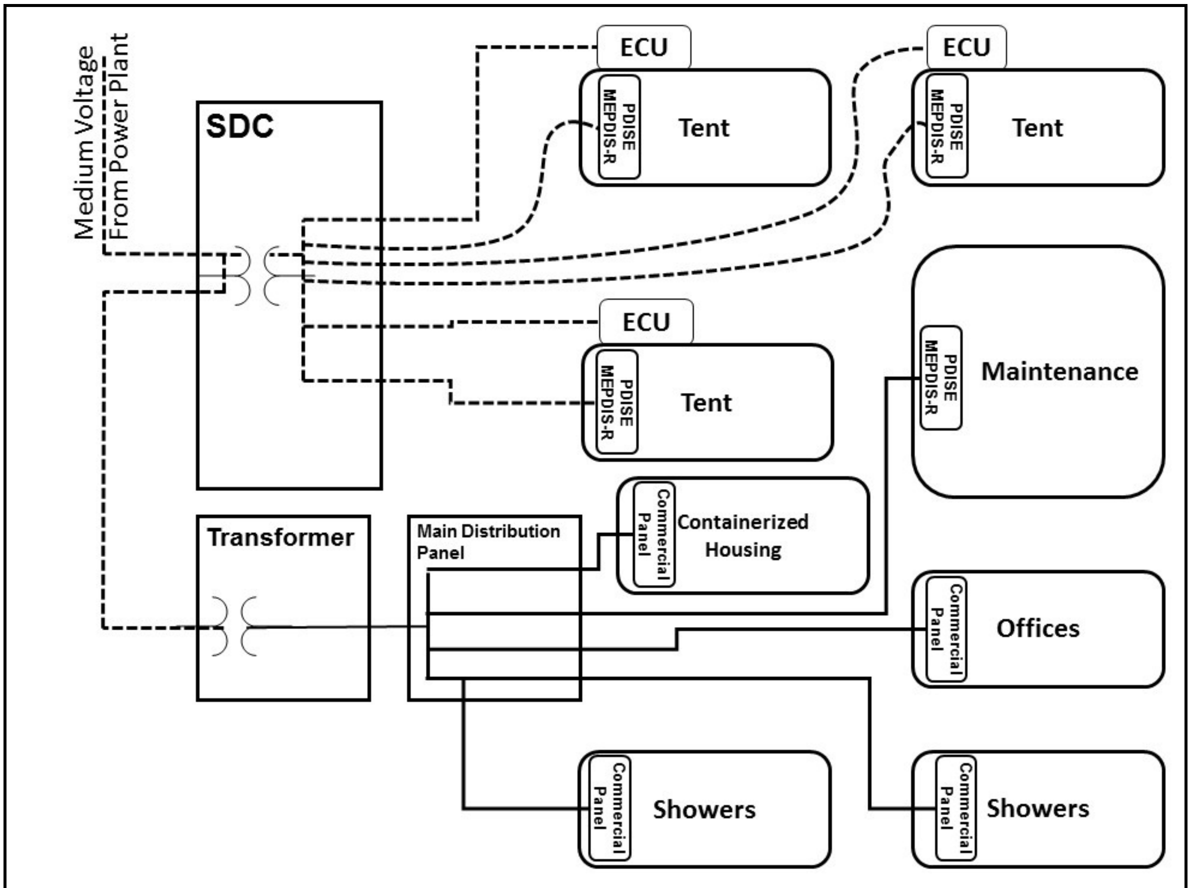


Legend:

ECU	environmental control unit
PSC	primary switching center
SDC	secondary distribution center
V	volt

Figure 3-3. Example of loop distribution—faulted

3-13. Primary distribution is at medium voltage to account for the voltage drop (line loss) that occurs over extended distances from the power source. Primary distribution voltage (medium voltage) is stepped down to secondary distribution (user level voltages) by distribution transformers or SDCs. See figure 3-4, page 3-6.



Legend:

———	commercial user-level voltage cable
– – – –	medium-voltage cable
ECU	environmental control unit
MEPDIS-R	Mobile Electric Power Distribution–Replacement
PDISE	Power Distribution Illumination System, Electrical
SDC	secondary distribution center

Figure 3-4. Typical simple secondary distribution network

SECONDARY DISTRIBUTION

3-14. Secondary distribution systems carry user level, low-voltage power to electrical loads. Secondary distribution systems can be surface laid, installed overhead, directly buried, or ducted underground, similar to primary systems. Chapter 5 discusses considerations during the power-planning process for selecting distribution methods and equipment. Appendix E provides specific information for power systems equipment.

3-15. SDCs are transformers with self-contained switching and protective devices. SDCs are advantageous for providing power to military operations because they are equipped with Power Distribution Illumination Systems, Electrical (PDISEs), or Mobile Electric Power Distribution–Replacement (MEPDIS-R) connections. Multiple SDCs can be employed in parallel without medium-voltage switching to increase capacity and distribute power over greater distances.

3-16. The first means of disconnect installed by interior electricians includes the main distribution panel, switched disconnect, manual transfer switch, automatic transfer switch, and switched fuse box at the structure. Prime power personnel install secondary distribution networks, but they are usually not used for work past the first means of disconnect in the secondary distribution system (or interior electrical work). Installing secondary distribution networks is performed by vertical-construction platoons, Marine Corps electricians, or contracted electricians. When installing a secondary distribution system, prime power personnel are responsible for making the connections up to the first means of disconnect.

SERVICE PRIME POWER REQUESTS AND CONTRACTING

3-17. Prime power requests for forces can be generated during deliberate or crisis action planning. These requests originate at the joint force or Service component command. Requests may also originate from other government agencies requiring support for domestic or foreign activities.

3-18. Prime power generation, distribution, and technical support are provided by military units, DOD civilians, or contracted services. The Army, Navy, and Air Force have prime power capabilities. Contracted prime power generation and distribution are commonly used for enduring bases and when load demand exceeds military prime power capabilities. For Service-specific detailed information about capabilities and capacities of prime power, see appendixes A through D.

3-19. Contracting is considered when the operational situation requires continuous electrical power, and it is anticipated that the military prime power capability will be exceeded. Exceptions to contracting may be considered for sites that preclude civilian access or require reliable power from military sources.

3-20. Base camp power contracts use various contract vehicles, including theater support contracts (executed by warranted contracting officials within the operational area) and external support (awarded by a contracting organization outside of the operational area). Electrical power plants are procured through military construction contracts, leases of equipment and services, or leases of government-furnished equipment.

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Chapter 4
Utility Electrical Power

This chapter discusses the challenges of planning and resourcing for transitioning power requirements to utility power systems. For any transition from organic to external capabilities, there are time and resource constraints, laws and regulations, customer coordination issues, and unclear or evolving missions. Primary challenges associated with power assets include theater entry conditions, mission duration, access to resources, and competing requirements and visions. Power assets and capabilities are integrated into the overall general engineering concept and employed to support the objectives of the theater civil engineer support plan. This planning process must occur long before action is needed—not as the need arises.

TRANSITION TO UTILITY POWER

4-1. Additional power systems equipment and support requirements may be obtained from external support contracts (such as a power contract or the Army Materiel Command Logistics Civil Augmentation Program task order) when base camp power requirements exceed packaged capabilities. Utility power is typically used when sustained electrical power is required at an enduring contingency base. Power system equipment is available through the General Services Administration or local contract sources and requires proper system design to ensure that equipment is used safely and efficiently.

4-2. In a deployed theater of operations, electrical power generation and distribution systems of the host nation may be considered for use. The key factors in the decision-making process include—

- Threats from enemy actions affecting continuous and reliable power.
- Reliability of the host-nation utility.
- Damage to the local electrical power generation and distribution system.
- Operational requirements.
- Capacity of the prime power capability to operate, maintain, and perform repairs to power production equipment of the host nation.

4-3. Despite being connected to utility power, critical assets may be powered separately, or they may have dedicated backup power generation capability in case of utility power outages. These requirements are identified early in the planning stages.

4-4. The DOD establishes a contract and a memorandum of agreement with a utility in the host nation to define the charges for consumption, demand, maintenance, and system monitoring in the event that it is prudent to transition to the host-nation grid system.

4-5. USACE supports transitions to host-nation utilities through reachback and deployable forward engineering support to joint force commanders. Teams conduct engineer reconnaissance (assessments and surveys) in support of the full range of reconstruction operations. USACE provides two types of forward engineering support teams: forward engineer support teams—advanced and forward engineer support teams—main.

4-6. The forward engineer support team—advanced provides additional engineer planning capabilities to combatant command and Army Service component command engineer staff, or it deploys in support of a joint task force. Capabilities include contracting, multiple engineer planning and design, and real estate acquisition and disposal. The forward engineer support team—advanced may also provide initial technical infrastructure assessments or surveys, contracting support, real estate acquisition support, and technical engineer assistance.

4-7. The forward engineer support team—main provides C2 of USACE teams and sustained USACE engineering execution capability in the joint operations area. This team supports a theater level headquarters or a joint force command. The forward engineer support team—main provides liaison officers and USACE engineering planning modules to support units, as required. It is a flexible, self-sustaining organization with a mission of providing the following USACE capabilities through forward presence and reachback mission areas:

- Contract construction.
- Environmental engineering.
- Geospatial engineering support.
- Infrastructure engineering planning and design.
- Real estate acquisition, disposal, and protection.
- Technical engineering expertise.

COMMERCIAL AND HOST-NATION UTILITY POWER

4-8. Throughout the life cycle of a base camp, the generation and distribution of electrical power service evolves from organic tactical generators to microgrids, prime power, and commercial or utility power that is supplied by a host nation. Detailed planning ensures the smooth transition from one form of generating electricity to another. Planning also addresses compatibility or interoperability between the various generation methods so that there are no adverse effects to organizations or mission-essential activities that are reliant upon electricity.

4-9. The Army has organic capabilities for establishing and maintaining critical infrastructure. USACE is responsible for Army and DOD military construction, real estate acquisition, and the development of U.S. infrastructure through the civil works program. Army base camp planners can obtain technical assistance on a variety of civil engineer topics from USACE. Planners most often seek advice on military construction and civil engineering contracts—especially contracts related to commercial or host-nation utility power service. The following paragraphs discuss factors to consider for the development of commercial utility service contracts or host-nation support agreements.

4-10. Operation and maintenance for utility power systems range from simple service contracts for operator level PMCS to full-service contracts that include daily operation, fueling services, and periodic maintenance and repair, as needed. A utility power system contract may include system construction and facility connections and repairs. The utility power system may use power system equipment that is provided by the contractor or purchased by the government to be used by the contractor, or it may use a tactical power system or deployable power system for which operational responsibility has been transferred to a contractor.

4-11. Acquisition and cross-serving agreements are applicable worldwide to acquire logistics services, supplies, and support directly from—or to provide them to—a foreign government or organization, such as the North Atlantic Treaty Organization; the American, British, Canadian, Australian, and New Zealand Armies Program; or the United Nations. See acquisition and cross-serving in agreements CJCSI 2120.01D and DODD 2010.09 for complete details, responsibilities, and procedures for acquiring and transferring logistics support, supplies, and services under the authority of 10 USC 2341 and 10 USC 2342.

4-12. Plans should allow sufficient time for base closure activities. It may be necessary to allow contracted support for a sustained power system 90–120 days or more prior to base closure to terminate service and to dismantle and remove power system equipment. Engineer prime power units can assess the power system and, if necessary, reestablish a deployable prime power system to support an orderly build-down process. As redeployment progresses, the power system eventually reverts to a tactical power system with unit responsibility. Additional tactical generators may be required for the final closeout. See ATP 3-37.10/MCRP 3-40D.13 for additional information on base closure.

Chapter 5

Electrical Power Planning

This chapter discusses the planning and resourcing considerations that are necessary in order to construct, operate, and maintain electrical power systems. The impact of details such as resource constraints, policies, regulations, laws, and mission variables can be significant. These details should be made available to planners prior to the development of electrical power system plans. The primary challenges associated with power assets are theater entry conditions, mission duration, access to resources, and competing requirements and visions. To maximize the use of limited resources, plans for electrical power systems should be integrated with general engineering and logistic/sustainment concepts of support. In most cases, this is accomplished during the deliberate planning process (MDMP/MCPP).

PLANNING CONSIDERATIONS

5-1. Electrical-power planning encompasses several factors, including equipment availability, mission variables, operational variables, power requirements, and funds available for contracted solutions. This chapter is designed to assist units in developing a safe and reliable power generation, distribution, and management plan. Units integrate electrical power requirements and capabilities into mission-planning and decision-making processes.

5-2. Deployed units initially rely on tactical generators for power needs. Power produced by low-voltage tactical generators can be replaced by military or commercial prime power generators. Once removed from daily use, tactical generators may function as backup power sources for critical mission applications if the need arises, be moved to other tactical locations, or be removed from service for sustainment level maintenance. Replacing tactical generators with prime power generators or utility power increases the reliability of the power source and saves wear and tear on tactical generators for temporarily deployed forces. Stand-alone prime power plants should be replaced with utility power as it becomes available. Military prime power plants should be considered as a temporary power solution for situations up to 18 months in duration. Prime power MOSs are low density in the Army. Units planning to switch to commercial prime power generation should purchase commercial generators through the Logistics Civil Augmentation Program, local contractors, or USACE contracts early in the planning process. Commercial generator purchases should address PMCS and fuel consumption considerations. In semipermanent base camps, stand-alone prime power plants may be replaced with utility power as it becomes available.

5-3. In some instances, it may be possible to connect multiple contingency bases to the same electrical power source (depending upon distance between the bases and the output of the shared power source). Likewise, as smaller unit bases are combined into one installation, a large base camp may be developed over time. Unit tactical generators are replaced by installation-level power (provided by prime/utility equipment). Ideally, tactical generators are replaced by SDCs or commercial transformers, which allow voltage transformation and distribution to the user-level voltage. Tactical generators may be retained as emergency backup for a mission-essential area or activity. Mission variables should be considered when planning for power system requirements.

MISSION

5-4. A thorough understanding of the mission and its anticipated duration helps with focusing the power planning process and desired outcomes. The mission statement clearly indicates the action, including both task and purpose, that must be taken by the organization. If an operation is of short duration, tactical generation may be the best approach to power systems. If the mission requires occupying or constructing a base camp, the selection of prime or utility power generation and distribution may provide benefits that outweigh resource investments. Similar plans are also appropriate for longer-term (such as 120 days or more) foreign humanitarian assistance or disaster relief missions. Mission type and length can also determine whether tactical spot generation or microgrids are more appropriate.

ENEMY

5-5. Electrical power is essential for the continuous operation of C2 centers, communication systems, and key weapon systems. Power generation and distribution assets should be critical. Friendly units can expect the enemy to use a wide variety of ground and aerial systems to detect power generation and distribution equipment and then attack with ground, naval, air, electromagnetic, or cyberspace weapons. Recognizing vulnerabilities allows planners to prepare defensive measures for mitigating threats to power system assets. Several factors affect power system survivability, including dispersion, mobility, redundancy, size, signatures (auditory, electromagnetic, infrared, and visual), camouflage, concealment, and deception. Cover and concealment or the shielding provided by terrain features and urban structures should be used, when available. See ATP 3-37.10/MCRP 3-40D.13 for more information on base camp planning. See ATP 3-37.34/MCTP 3-34C for more information on hardening key and critical infrastructure, including power generation systems.

5-6. Utility power systems potentially represent a critical vulnerability for an adversary. Electrical infrastructure assessments may tie into intelligence preparation of the battlefield activities, enabling offensive operations and removing key adversary capabilities. Detailed infrastructure assessments enable the selection of specific targets without widespread devastation of a utility power grid. See ATP 2-01.3/MCRP 2-10B.1 for more information on intelligence preparation of the battlefield/battlespace activities.

TERRAIN AND WEATHER

5-7. Terrain and weather affect the operation of power generation equipment and the routing of distribution cables. For example, the power output of generators decreases by 3.5 percent per 305 meters (1,000 feet) of elevation above 1,219 meters (4,000 feet). Also, equipment operating temperatures increase which at higher altitudes (because thinner air is less efficient at dissipating waste heat), when left in direct sunlight, and because of protection measures that may limit cooling air flow (berms, walls, and overhead cover). Likewise, rugged terrain and dense vegetation affect the placement of power systems and distribution cables. Relatively level surfaces are required for generators; clearing and leveling an area before installing generators may sometimes be necessary. Equipment technical manuals should be consulted for terrain and weather effects on specific equipment.

5-8. Weather and other climatic conditions also affect power generation equipment. Temperature extremes require the availability of additional authorized listed supplies or the use of organizational items to mitigate the impact of these variables. Tropical and coastal regions require additional equipment maintenance to prevent corrosion from humidity and salt spray. Desert regions require frequent maintenance due to the heat and dust. Grounding problems are often encountered in dry climates due to the high resistance of typical desert soils. In addition to the applicable power source technical manuals, *PS: The Preventive Maintenance Monthly* magazine for the Army contains multiple articles on operations in various climatic conditions. See the references section of this publication for more information.

TROOPS AND SUPPORT AVAILABLE

5-9. The effectiveness and reliability of power systems are dictated by the availability of qualified operators, maintainers, and external support, per AR 385-10 or MCO 5100.29B. The level of power system sustainment support necessary is determined by the level of the power system. Logistic support—including expected time and quantities of fuel deliveries, consumable and repair parts, and lubricants and access to replacement equipment—is made available to personnel who are operating or maintaining power generation and distribution equipment.

TIME AVAILABLE

5-10. The type of power system employed is highly dependent on time available—both in terms of the boots-on-ground timeframe and the total mission length. Constructing the best power system at the start of a mission may not always be feasible due to time constraints. In these instances, planners should develop a course of action to upgrade the unit power system over appropriate timelines as resources become available.

CIVIL CONSIDERATIONS (ARMY ONLY)

5-11. Civil considerations—including organizations, the civilian utility power infrastructure, the local populace, and activities of civilian leaders—influence the conduct of military operations. Civil considerations also include actual structures, geographic areas, local utility capabilities, and events. All these variables can affect the emplacement, operation, and security of power systems.

POWER MANAGEMENT

5-12. Managing electrical power is like managing other resources. Monitoring and controlling responsibilities ensures that the production of power is reliable, meets mission needs, and incorporates efficiencies. Managing power usually involves the following actions:

- Advising the commander of the overall power system status and efficiency.
- Coordinating power system changes as unit mission needs change.
- Educating personnel on efficient electrical power use.
- Ensuring that personnel understand their roles and responsibilities.
- Monitoring the fuel consumption of fuel and other resources needed to produce power.
- Understanding and monitoring the demand for unit power needs over time.

POWER MANAGEMENT CONSIDERATIONS

5-13. Power management sustainment supports the commander's ability to sustain the force by adhering to the following principles of sustainment:

- **Anticipation.** *Anticipation* refers to the ability to foresee operational requirements and initiate necessary actions that most appropriately satisfy a response without waiting for operations orders or fragmentary orders (ADP 4-0). It is shaped by professional judgment resulting from education, experience, knowledge, doctrine, regulations, and creativity. When properly integrated, power managers assist commanders and staffs by planning and initiating necessary processes to meet anticipated power requirements.
- **Continuity.** *Continuity* refers to the uninterrupted provision of sustainment across all levels of war (ADP 4-0). It is a key issue in sustained operations as units rotate through the theater. Power management personnel provide continuity of command through power generation and distribution systems.
- **Economy.** *Economy* refers to providing sustainment resources in an efficient manner that enables the commander to employ all assets to the greatest effect possible (ADP 4-0). Operational energy requirements are reduced by consolidating fueling requirements, generator engine hours, and electrical distribution equipment to only that which is needed to operate efficiently in a forward theater.
- **Improvisation.** *Improvisation* refers to the ability to adapt sustainment operations to unexpected situations or circumstances affecting a mission. It is the capability to modify and adapt the power generation and distribution systems and resources to meet current, future, and unexpected operation conditions in any theater (ADP 4-0). Power managers understand power generation and distribution systems and requirements in a manner that enables them to make complex systems work with materials that are on hand or are easily obtainable.
- **Integration.** *Integration* refers to combining all the sustainment elements within operations assuring unity of command and effort (ADP 4-0). Power management combines the assets (equipment, knowledge, personnel) within supported units to facilitate and maximize a more

sustainable power generation system. The ideal integration of power occurs at multiple levels within an operational area, encompassing personnel planning factors from the lowest commander through the theater.

- **Responsiveness.** *Responsiveness* refers to the ability to react to changing requirements and respond to meet the needs to maintain support (ADP 4-0). Tactical power systems are regularly available for deployment into different operational areas throughout the world.
- **Simplicity.** *Simplicity* refers to processes and procedures to minimize the complexity of sustainment (ADP 4-0). Simplicity in the power grid reduces unnecessary spot generation, where applicable, and integrates more efficient forms of generation and distribution.
- **Survivability.** *Survivability* refers to all aspects of protecting personnel, weapons, and supplies while simultaneously deceiving the enemy (JP 3-34). Survivability improves through the distribution and reduction of a unit signature.

Five-Step Power-Planning Process

5-14. Like the way in which mission variables are used in the military decision-making process and Marine Corps planning process, the five-step power-planning process can be used to design and emplace power production and distribution systems. This cyclical process enables planners to compensate for changes in power requirements as missions change. Figure 5-1 depicts the five-step power-planning process used to develop power production and distribution layouts.

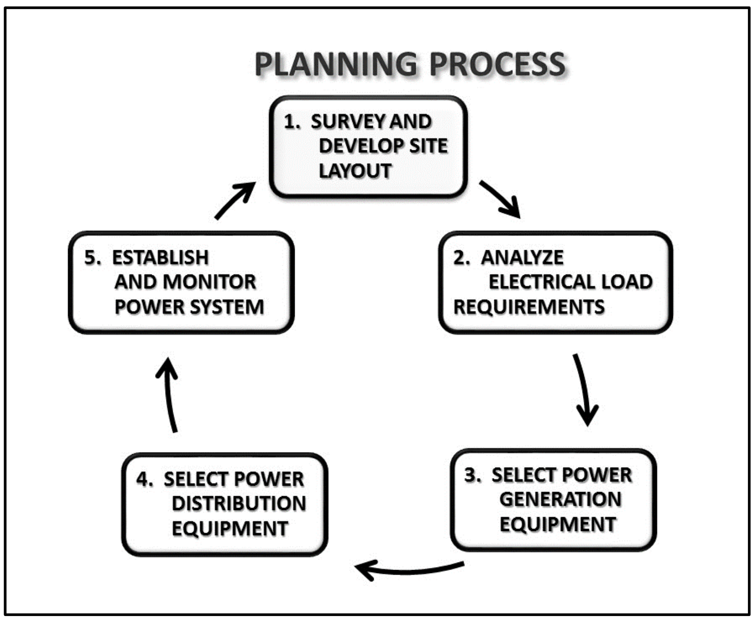

Figure 5-1. The five-step power-planning process

5-15. The first four steps of the power-planning process produce a power system layout based on the power needs of the unit. These steps result in a diagram that identifies the locations of electrical loads, power sources, and power distribution equipment. The final step involves establishing and monitoring the power system. Establishment is accomplished by individuals who are trained to perform emplacement tasks according to the applicable technical manuals. During the monitoring process, designated operators ensure that the power system is operating efficiently in order to conserve fuel and reduce mechanical failure.

Step 1–Survey and Develop Site Layout

5-16. Most units maintain a written tactical standard operating procedure (SOP). A unit SOP provides planning data and details about how the unit establishes and operates the unit command center. The planning data can include diagrams depicting the location of individual sections inside specific command center tents, areas designated for briefing and for storing classified material, perimeter security, and the equipment necessary to operate the command center. Power planners can use the list of equipment in the SOP to develop an estimate of the electrical power required by the command center. Power planners review the notional layouts to develop power system site layouts. The tactical situation, the location of critical loads, terrain, time, and resources should be considered when placing power systems and distribution equipment. The tactical situation may preclude ideal layouts; but as time permits and circumstances change, improving the power layout should also be considered. Host-nation-imposed environmental restrictions may affect preferred layout techniques—for example, restricting or prohibiting the burial of power distribution lines. Once the unit arrives at a deployed location, the power planner walks the terrain and marks the locations of all items on the layout to assess them using the following criteria:

- **Adequate space around generator sets.** There must be adequate space between generator sets and other items (shelters and other systems) for airflow, grounding, maintenance, and refueling operations. The terrain where a generator set is to be placed is evaluated for suitability in terms of grade/slope (should be level), drainage, and soil hardness (to support the weight of the generator). Sometimes it is necessary to use logs, planks, or other shoring materials to prevent the skids or frame from sinking into soft soil. All protection requirements must be considered.
- **Distance from the power source to the load.** Ideally, the source-to-load distance for tactical generators should be 15–46 meters (50–150 feet) with a 91-meter (300-foot) maximum. For prime power generation equipment, medium-voltage distribution distances can be up to several miles. However, the maximum distances between the transformer and the low-voltage loads follow the same 300-foot rule.
- **Generator exhaust and noise.** The way in which the emplacement of generator sets affects nearby structures, work and sleep areas, and equipment should be considered. It is important to emplace power sources far away from work and sleep areas to minimize noise effects and allow engine exhaust to dissipate. In addition, (depending on the ISR capability of the enemy) signature management should also be considered when placing generators.
- **Location of large demands.** The location of the generator set can affect the overall efficiency of the power system. Power production should be placed close to load centers. It might sometimes be necessary to place additional generator sets in parallel to meet large demand, leaving room for increased future power requirements.
- **Vulnerability and exposure of the power source and load cables.** Vulnerability and exposure are affected by the proximity of personnel and vehicle traffic to the cables. If practical (and the tactical situation warrants it), load cables should be buried according to technical manual specifications. Damaged cables present a dangerous electrical shock hazard and degrade power surety. Constructing an overhead shelter for a generator set can provide protection from environmental exposure (sunlight). This can be considered if the unit remains on-site for an extended period of time, the threat condition level is favorable, and the tactical situation is stable.

Step 2–Analyze Electrical Load Requirements

5-17. Preliminary tasks that the power manager should complete before selecting power sources and distribution equipment include computing the load, determining the load cable requirement, and balancing the load. This ensures that the most efficient system is employed and reduces the logistical burden. This processes also used to determine if the unit needs 100 percent redundancy (emergency power) for critical systems (C2, communications, and direct patient care activities). The preliminary analysis of the electrical power required by a unit should be periodically reexamined. Aspects to reexamine include verifying whether the load has significantly increased (due to the arrival of additional personal and electrically powered equipment) and determining if the loads remain balanced. Table 5-1, page 5-6, depicts considerations for electrical power systems.

Table 5-1. Electrical power system considerations

ORGANIC (UP TO 90 DAYS)		
Electrical Power System Attributes	***Load and Situational Attributes***	***Operational Considerations***
• Organic tactical generator: tactical power plant connected to a single load at user voltage. • Power sources remain separated.	• Primarily user loads: C2; communications; weapons and weapon systems; field feeding; and essential maintenance, heating, ventilation, and air conditioning systems.	• Mobility and rapid setup for supporting combat operations override other considerations. • Organic equipment is operated by individual users. • The ability to rapidly displace improves survivability (and helps achieve signature management).
INITIAL (COMPANY/BATTALION/BATTALION LANDING TEAM) (UP TO 6 MONTHS)		
Electrical Power System Attributes	***Load and Situational Attributes***	***Operational Considerations***
• Creation of tactical microgrids using organic power generation equipment and the inclusion of additional generation and distribution resources. • Initial consolidation of power sources.	• Large tactical operations centers, supply and maintenance, laundry facilities, shower facilities, dining facilities (including refrigerated and frozen storage), life support areas (bed down including heating, ventilation, and air conditioning).	• Deliberate system planning and coordination requirements. • Tactical power plant(s) and PDISE equipment organic to operations section and operated by assigned personnel, individual unit organic power equipment operationally controlled by operations section.
INITIAL (BRIGADE COMBAT TEAM) (UP TO 6 MONTHS)		
Electrical Power System Attributes	***Load and Situational Attributes***	***Operational Considerations***
• Tactical prime power system, medium-voltage power generation and distribution system, SDCs (transformers) replace tactical power plants. • Tactical microgrids are consolidated into prime power plant.	• Water purification and distribution; ice production facilities; morale, welfare, and recreation facilities; gymnasiums; fitness centers; Army and Air Force Exchange Services or Navy Exchange.	• Base camp master planning is required. • Prime power platoon continues to augment utility companies to install, operate, and maintain prime power system. Tactical power plants serve as redundant backup or can be reallocated to other sites.
TEMPORARY (UP TO 5 YEARS)		
Electrical Power System Attributes	***Load and Situational Attributes***	***Operational Considerations***
• Tactical prime power system: power system expansions as needed; distribution system expansion or improvement. • Improved facilities designed to utilize waste heat from generators to preheat water for showers and laundry to reduce fuel consumption.	• Initial standard loads plus: expanded morale, welfare, and recreation facilities; Army and Air Force Exchange Services or Navy Exchange vendors; theater level maintenance; and supply activities. • Improved or consolidated dining facilities, improved shower and laundry facilities.	• Base camp or installation master planning is required. • Prime power platoon continues to augment utility companies for power system operation and maintenance. Transition from tent-based facilities to improved facilities takes place.

Table 5-1. Electrical power system considerations (continued)

SEMIPERMANENT (2 to 10 YEARS)		
Electrical Power System Attributes	***Load and Situational Attributes***	***Operational Considerations***
• Transition to utility power system (military construction, LOGCAP, USACE, contract, and commercial power). • Tactical prime power equipment retrograded to Army pre-positioned stocks (war reserve) program; considerations for renewable energy.	• All facilities connected to consolidated power system. • Expeditionary power systems (isolated generators or microgrids within overall system) eliminated.	• Base camp or installation master planning is required. • Long-term civilian contract (LOGCAP or similar) is in place for operations and maintenance. Utility company personnel serve as contract QA oversight.

Legend:

C2	command and control	SDC	secondary distribution center
LOGCAP	Logistics Civil Augmentation Program (Army)	QA	quality assurance
PDISE	Power Distribution Illumination System, Electrical	USACE	U.S. Army Corps of Engineers

Step 3–Select Power Generation Equipment

5-18. This step includes the identification of the power source (tactical, prime, utility) that is most suitable for meeting the power requirements. After determining the loads and notating them on the site layout, the power manager selects the power source needed to match the load. The DOD standard family of tactical generators can fulfill most organic power requirements. Prime power systems can be selected when distances and loads exceed those of tactical power systems. Utility power can be selected if it is compatible with mission equipment and reliable enough to suit the needs of the unit. For more information on international operability of electrical power systems, see appendix H.

Step 4–Select Power Distribution Equipment

5-19. Units have several options for electrical distribution systems and components. Effective distribution often reduces the number of generator sets needed, can save fuel, and can reduce maintenance. PDISE and MEPDIS-R allow the unit to assemble and operate a safe tactical power grid in all operational environments.

5-20. Medium-voltage power generation includes a primary and secondary distribution system to carry medium-voltage power from the power plant to transformers. SDCs are transformers with self-contained switching and protective devices that are equipped with PDISE or MEPDIS-R connections. Commercial distribution transformers can also transform medium-voltage levels to user-level voltages, but PDISE and MEPDIS-R may not have a connection interface.

5-21. Primary and secondary distribution systems can be surface-laid, installed overhead, directly buried, or ducted underground. The following are planning considerations for the various methods of distribution system installation:

- Surface-laid distribution is the typical initial format used due to the speed of installation. However, this solution is temporary because of the susceptibility of damage; in addition, mobility on the base camp may be restricted. The cables can be recovered for reuse at another location. Although armored and heavily jacketed cables are bulky and heavy and require material-handling equipment for installation, they are more resistant to damage.
- Overhead distribution systems are the easiest types of distribution systems to troubleshoot and maintain but are also more likely than underground distribution systems to be damaged due to exposure. Overhead distribution systems are the least expensive, quickest to install, and most readily expandable distribution systems for covering large areas over long distances. Traditional overhead systems were built with wooden poles, wooden cross-arms, and ceramic insulators, but

newer systems include fiberglass, concrete, or tubular metal poles and composite insulators. Overhead distribution systems require specialized equipment for digging, erecting, and setting poles, and stringing overhead conductors. Although the conductors are usually about 9 meters (30 feet) above the finished-grade surface, special precautions are taken at road crossings or other areas where tall vehicles (cranes and raised forklifts) are used.

- Because direct-burial distribution is more time-consuming to install and repair due to the horizontal construction resources required, it is a semipermanent type of distribution. Trenches can be dug with readily available engineer equipment (backhoes or excavators) or dedicated trenching machines, and the cables are bedded on sand in the bottom of the trench. Marker tape should be installed above the cables according to military or host-nation standards. Installing a direct-buried distribution system may be challenging in extremely rocky soils.
- Ducted underground distribution systems are generally used in permanent urban locations where system expansions or modifications are unlikely. Access vaults are emplaced at regular intervals 91–122 meters (300–400 feet) to provide access points for splicing, maintenance, and repair. Additional testing, pumping, and ventilation equipment may be required to allow confined-space access into the vaults. Individual training and safety procedures must be established. Ducted underground distribution systems are the most resource-intensive to install and the least readily adaptable to changes or modifications, but these systems are reliable because of protection from physical damage.

Step 5–Establish and Monitor Power Systems

5-22. This step includes installing the system according to the site layout plans and appropriate technical guidance and publications. The power manager and operators monitor and manage electrical power output. The power manager then directs adjustments as needed to maintain an efficient, safe, and reliable system to support the unit mission.

JOINT CONSTRUCTION MANAGEMENT SYSTEM

5-23. The Joint Construction Management System (JCMS) is a software suite that allows users to access the Army Facilities Components System (AFCS) (Advanced Base Functional Component for Marine Corps readers) designs, logistics, and planning data for initial and temporary construction. JCMS is an interactive system that allows planners to estimate bills for materials and labor and equipment requirements for each construction mission. It assists in the selection of base camp design templates and facilities through consideration of theater priorities, standards of construction, resource constraints, and climate.

5-24. As directed by AR 415-16, the AFCS serves as a repository of standardized joint contingency facilities and installation designs and associated construction data used for Army service component command war planning and Army force modeling. The AFCS provides users with an automated tool that supports the logistical and engineer planning of contingency bases and the planning and execution of construction activities. The AFCS program provides the JCMS software suite to support the joint engineer community.

5-25. While JCMS includes tools for site selection, design, and construction, the Master Planning Module also provides power system analysis and design. The JCMS Master Planning Module is a CAD-based design tool that allows two-dimensional drawings of base camp facilities and equipment to be arranged on scaled map layers; connected with cables, hoses, and ducts; and assessed for resource consumption, given specific operational and environmental scenarios under which a camp is expected to operate.

5-26. The Master Planning Module provides estimates of peak and average power demand at the facility level. Users can also check power distribution equipment and cables outside of each facility to verify that loads do not exceed capacity. Master planning enables visualization of map data to influence layout, sharing and organization of optimal designs, and the development of kits for rapid fielding. Ultimately, it also helps to modernize master planning for the joint force.

AUTOMATED DISTRIBUTION ILLUMINATION SYSTEM, ELECTRICAL

5-27. AutoDISE is a software tool for assisting units in planning safe and effective power systems that support the mission. AutoDISE uses an intuitive graphics interface to aid in designing microgrid layouts with a variety of military standard power systems. Using AutoDISE enables a trained electrician to create a virtual layout including shelters, electrical loads, distribution equipment, and generators based on the unit table of organization and equipment (TO&E). Once the basic layout is complete, the AutoDISE program produces a wiring diagram that depicts the virtual layout. AutoDISE features multiple advancements for planners, including the ability to produce an electrical equipment list based upon the layout specified and to estimate fuel consumption for the generator sets selected for the layout. Phase load information is also provided so that the user can better balance the load.

5-28. AutoDISE is a stand-alone client application. An individual can download it from the software center or run it directly from a CD. AutoDISE is available from the Project Manager Expeditionary Energy & Sustainment Systems (PM E2S2). AutoDISE can be installed on DOD computer systems. The information for using AutoDISE that is contained in TM 9-6150-226-13 (for Army users) and TM 6110-OI/1 (for Marine Corps users) takes precedence over information in the AutoDISE user manual and software.

5-29. Figure 5-2 depicts a notional three-dimensional internal AutoDISE power distribution layout. An outside layout that includes generators and distribution equipment is also available with AutoDISE.

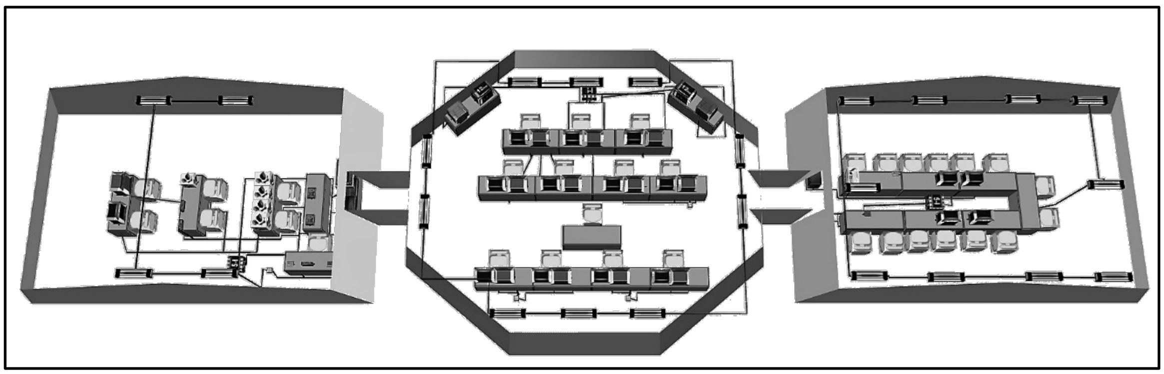

Figure 5-2. Notional AutoDISE power distribution layout

REACHBACK RESOURCES

5-30. The U.S. Army Corps of Engineers Reachback Operations Center (UROC) at the U.S. Army Engineer Research and Development Center (ERDC) provides a "reachback" engineering capability that supports contingencies across the range of military operations. The UROC rapidly leverages the extensive resources of the Army Corps of Engineers for supporting deployed forces or those requiring specialized assistance.

5-31. The UROC enables DOD personnel deployed worldwide to talk directly with experts in the United States when an engineering problem in the field needs quick resolution. Deployed forces can be linked to subject matter experts within the government, private industry, or academia to obtain solutions to complex field problems. The UROC can be contacted at 1-877-ARMY-ENG or 601-634-2439; Defense Switched Network (DSN) 312-446-2439; or e-mail: <uroc@usace.army.mil> (secure e-mail: <uroc@usace.army.smil.mil>). The UROC Web site is (secure Web site: https://uroc.usace.army.smil.mil).

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Appendix A
Army Electrical Power Capability

POWER GENERATION AND DISTRIBUTION SPECIALISTS

A-1. Multiple MOSs are able to provide a supporting role in the planning, preparation, execution and assessment of tactical power generation and power distribution systems to best meet power requirements. These MOSs include Engineer Officer 12B, Construction Engineer Technician 120A, General Engineering Supervisor 12X, Construction Engineering Supervisor 12H, Prime Power Production Specialist 12P, Transmission and Distribution Specialist 12Q, Interior Electrician 12R, and Tactical Power Generation Specialist 91D. The MOSs work with and advise the unit power manager to ensure that the unit power requirements are met. For a detailed description of the duties and responsibilities, see DA PAM 611-21.

PRIME POWER RESPONSIBILITY

A-2. Engineer prime power units are theater level assets. Prime power units are assigned or attached to the senior engineer headquarters in the theater and are normally employed in a general-support role throughout the theater.

A-3. Army prime power units provide continuous, reliable, commercial-grade, and medium-voltage power for the support of military operations. These units are typically used when commercial power is unavailable or where tactical generators are impractical. Therefore, prime power supports operations across the competition continuum. Prime power units support general engineering efforts theater-wide by providing advice and technical assistance on all aspects of electrical power. Also, prime power efforts and capabilities are integrated and synchronized with general engineering efforts to achieve the effects intended within the theater engineer support plan.

A-4. Army prime power personnel provide electrical power expertise, technical assistance, and contracting support on all aspects of electrical power and distribution systems. Army engineer prime power units provide support to military operations worldwide. The support tasks include the following responsibilities:

- Conduct electrical-load surveys, analyses, and designs of power distribution systems.
- Deploy, install, operate, and maintain power generation and distribution.
- Perform damage assessments of organic, nonorganic, and host-nation distribution systems.
- Provide power-related planning and staff assistance.
- Serve as the SME for power-related contracts.

CONDUCT ELECTRICAL-LOAD SURVEYS, ANALYSES, AND DESIGNS OF POWER DISTRIBUTION SYSTEMS

A-5. An electrical-load survey is an analysis of power requirements. The electrical-load survey is a vital step in providing prime power support. The prime power team conducts the electrical-load survey to determine the supported power and distribution requirements of a unit. The electrical-load survey also determines the required level of reliability and identifies special power demands or problems. The recommended power source is determined based on the electrical-load survey. A thorough electrical-load survey is completed before installing a power plant or designing a distribution system.

DEPLOY, INSTALL, OPERATE, AND MAINTAIN POWER GENERATION AND DISTRIBUTION

A-6. Army prime power units produce commercial grade power with organic generators. These units may also install, operate, and maintain nonmodified TO&E power generation equipment and fixed commercial power plants. Power generation and distribution capabilities are used in a variety of base camp configurations and seaports, airfields, C2 nodes, and other critical facilities. The power generation capability of the unit allows it to operate, maintain, and perform damage assessments of fixed commercial diesel engine power plants. Prime power units have a reachback capability for sustainment level maintenance for deployed equipment.

A-7. Army prime power personnel can install and maintain temporary, primary, and secondary distribution systems. Distribution systems are designed, maintained, repaired, and constructed with approved materials and methods, including appropriate protective devices. Prime power personnel also repair critical infrastructure when mission-critical needs arise. By the time the local user is aware of an outage, the personnel working at the power generation plant are already in pursuit of the issue and working toward its repair. Prime power personnel can make connections to existing distribution networks. Construction and maintenance of extensive overhead distribution systems should be accomplished using contracts or U.S. Army Reserve power line platoons within the prime power battalion.

A-8. Although prime power personnel can perform interior electrical work, they are typically not used for this task. Interior electrical work is usually performed by vertical-construction platoons or contracted electricians. When installing a secondary distribution system, prime power personnel are responsible for the service entrance and for making connection to the first circuit panel overcurrent device or first piece of service equipment. Service equipment, which is installed by interior electricians, includes the main distribution panel, switched disconnect, manual transfer switch, automatic transfer switch, or switched fuse box at the structure.

PERFORM DAMAGE ASSESSMENTS OF ORGANIC, NONORGANIC, AND HOST-NATION DISTRIBUTION SYSTEMS

A-9. Prime power platoons assess damage to existing distribution systems. The prime power team performs inspections and electrical testing to identify damage. Prime power personnel may provide an after-action report outlining the damages found and produce a bill of materials for electrical equipment needed to make repairs to the electrical system.

PROVIDE POWER-RELATED PLANNING AND STAFF ASSISTANCE

A-10. The prime power unit provides power-related technical assistance to the appropriate engineer staff of an operational unit or the BOS-I. This assistance also includes support with electrical generation capacity, distribution, installation, maintenance, and repair of the power systems involved. The Prime Power Production Specialist 12P is the theater SME for electrical power.

A-11. The prime power battalion supports the commander’s capability to conduct DSCA within the force by adhering to the following principles that are outlined in ADP 3-28:

- **Engaged partnerships.** Prime power is engaged with the Corps of Engineers to work with state and local emergency power managers and governments regarding operational and operation requirements and readiness. This partnership allows the prime power unit to respond immediately to disaster situations. This alliance can minimize power interruptions to critical facilities and enable states or local municipalities to provide lifesaving services.
- **Readiness to act.** The prime power company has three platoons that remain at a constant state of readiness to deploy to a disaster zone when called upon. Prime power personnel have 18 hours from the notification of an event to arrive on-site ready to respond.
- **Scalable, flexible, and adaptable operational capabilities.** Prime power personnel can deploy in five different element configurations in support of the Corps of Engineers response and recovery operations under the National Response Framework ESF #3, Public Works and

Engineering activities. This scalable response allows prime power personnel to use power generation and distribution expertise where there the need is greatest and without delay.

- **Tiered response.** The Corps of Engineers provides a tiered response through operations with several different agencies and prime power support units. This response allows the Corps of Engineers to have the right people in the right place talking to the right agencies for the assistance that is required.
- **Unity of effort through unified command.** Prime power personnel deploy as part of a Corps of Engineers power response team. This allows prime power operations that take place in disaster areas to be synchronized to achieve the maximum synergistic effect. The power response team coordinates with the state emergency operations team to streamline power requirements during disaster operations.

SERVE AS THE SUBJECT MATTER EXPERT FOR POWER-RELATED CONTRACTS

A-12. The prime power unit provides power-related technical assistance to representatives of the contracting office, USACE, the Defense Contracting Management Agency, and others. Prime power engineers help develop the specifications for performance contracts and purchase contracts for electrical material and power sustainment operations. This assistance includes reviews of scopes of work and bills of materials. In addition to developing the specifications for contracts, prime power engineers also help review the technical evaluation of bids received. When acting as a contracting office representative, prime power engineers can conduct inspections and accept duties that are in line with the maintenance and operation of power plants and distribution equipment. This assistance is available for military units and supporting USACE personnel.

ARMY PRIME POWER BATTALION

A-13. The Army trains, organizes, and equips the 249th Engineer Battalion (Prime Power) to provide worldwide prime electrical power generation to support military operations and the National Response Framework. The 249th Engineer Battalion provides prime power support, specialized logistical and technical expertise on power generation, and distribution (including design and analysis capabilities) to commanders and staffs. The battalion manages and coordinates worldwide prime power requirements for the Army. The battalion has three regular Army companies and one U.S. Army Reserve company.

PRIME POWER COMPANY

A-14. A prime power company consists of one headquarters platoon and four prime power platoons. The engineer prime power company headquarters provides administrative and limited logistics support (including specialized Class IV, VII, and IX support) to subordinate prime power platoons.

PRIME POWER ENGINEER PLATOON (POWER STATION)

A-15. The prime power engineer platoon is the basic building block for the company and battalion. The platoon is the smallest deployable element of the battalion. Once the prime power platoon is deployed, it conducts assessments, creates plans, and begins construction of power plants and associated distribution systems across an installation, base, or theater of operations. Once construction is completed, prime power platoons focus on operations and maintenance of the power plant and the associated distribution systems.

A-16. The platoon is composed of two sections, with prime power production and interior electrician capability. Each prime power platoon has one organic power plant with four mobile electric power ([MEP]-810B) power units. The platoon personnel are skilled in maintaining the platoon power generation equipment and performing maintenance of overhead power distribution equipment.

A-17. The distribution system allows the platoon the ability to deploy and provide power in the deployed locations. Prime power platoon organic distribution equipment serves as an interim solution for power distribution. The prime power platoon can provide a plant operating center, maintenance area, and tool and test equipment storage area. Power distribution systems that are anticipated to operate longer than 18 months should be replaced with permanent systems.

A-18. When planning for prime power operations that involve the employment of a prime power platoon or multiple platoons in support of enduring operations, it is important to ensure that the heavy maintenance section (HMS) is included in the planning process. The sustainment of those Platoons may require support from HMS—either in the theater of operations or from the HMS home station. Maintenance Support Teams (MSTs) may deploy on a temporary duty basis to assist with handling upper-level maintenance requests or with ordering, obtaining, and shipping critical parts (engines, alternators, and other specialized equipment).

SAFETY AND STANDARDS OFFICE HEAVY MAINTENANCE SECTION

A-19. The battalion can employ a mix of organic military and commercial off-the-shelf (COTS) equipment. Sustainment level maintenance of this equipment is performed by HMS personnel. Section personnel also oversee safety and develop standards for operating procedures.

A-20. HMS is a 249th Engineer Battalion Staff element that is comprised of two shops to support two separate missions led by an MOS 120A (chief warrant officer three) and an MOS 12X5O with extensive prime power experience.

A-21. The first HMS shop is comprised of four MSTs. Each MST is made up of five prime power soldiers. Of these five Soldiers, each team has three prime power mechanics, one instrumentation specialist, and one electrician. Team personnel are trained and certified to rebuild the engine of the MEP-810B power unit. They also receive training on other nonorganic engines, electrical systems, and more advanced electrical control systems to support the use of other COTS items that link from tactical to commercial power.

A-22. HMS can deploy as an entire section or as individual MSTs. However, the level of maintenance that is performed requires specialized facilities to support the mission. The HMS and the MSTs completely rebuild engines, which requires an environmentally sealed facility that has a welding shop and overhead lift support. If HMS was deployed, they would be best employed near an Army Material Command hub.

A-23. The second HMS shop known as the Safety and Standards Office (SASO). The SASO reports directly to the 249th Engineer Battalion commander to implement the Corps of Engineers Safety and Occupational Health Management System within the battalion. The SASO conducts job hazard analysis and position hazard analysis in support of the 249th Engineer Battalion mission. The SASO oversees accident reporting and near-miss reports and assists with safety investigations, if required. The SASO also performs scheduled and unscheduled inspections of prime power companies and their platoons to ensure compliance with the battalion Corps of Engineers Safety and Occupational Health Management System program and the use of safe work practices.

A-24. Due to the hazardous nature of the electrical systems employed by battalion personnel, specialized COTS personal protective equipment (PPE) is used. The SASO manages the battalion inventory of COTS PPE. Other duties include ordering, receiving, testing, and issuing COTS PPE to battalion personnel. COTS PPE requires specialized testing to verify that it is serviceable. To prevent erroneous test results, personnel who perform the testing are trained to properly operate the testing equipment.

EQUIPMENT AND EQUIPMENT LOGISTICAL CONSIDERATIONS

A-25. Prime power stations are ready to deploy worldwide upon tasking by the USACE Operations Center. All organic equipment (generators, cables, control vans, and transformers) can be transported on flatbed or lowboy trailers. The MEP-810B has a power production capacity of 840-kW, is trailer-mounted, and is certified by the Department of Transportation for highway travel speeds of up to 55 miles per hour. The power units require a 915-series tractor or commercial equivalent for movement. Organic equipment can also be moved by Army helicopters or by strategic airlift.

A-26. Planning factors for deploying a power plant depend on load, time, and available personnel. Planners should consider management, power plant operations, safety, maintenance, and material handling when they develop personnel estimates. Table A-1 describes planning factors for the personnel required to sustain a power plant using 8- to 12-hour shifts safely and continuously. A fully staffed power station can install power production and distribution to a 1,000-man force provider base camp in approximately 14 days. The number of personnel and time required varies based on mission variables.

A-27. A sustainable load is equal to 60–80 percent of the maximum load of a generation system. In the case of a 3.4-megawatt system, five generators are operating, and one is in maintenance or "surge load reserve." Five generators create 4.2 megawatts of electrical power; therefore, 3.4 megawatts is at 80 percent efficiency of the maximum load.

Table A-1. Prime power planning factors

Sustainable Load (60–80% max)	*Power Units Required*	*Prime Power Personnel Required to Install Generation and Distribution*	*O&M of Generation*	*O&M of Distribution*
1.7 MW	4	18	14	4
3.4 MW	6	19	14	5
5.1 MW	8	22	17*	6
* An additional maintenance team is required to maintain eight MEP-810s.				

Legend:

%	percent
max	maximum
MEP	mobile electric power
MW	megawatt
O&M	operations and maintenance

A-28. Prime power platoons require heavy materials-handling equipment support to mobilize, install, and demobilize equipment after deployment and redeployment. A 40-ton crane (with appropriate rigging equipment), rough-terrain container handler, and 10,000-pound rough-terrain forklift can support this requirement. Operations involving erecting or repairing and making connections to overhead distribution networks require the use of a line truck, which is organic only to the Reserve Component power line platoons.

A-29. Deployed prime power platoons require support from the higher headquarters to which they are attached or that has operational control of them for all classes of supply. The operation of a prime power plant requires a daily resupply of diesel fuel 2 or jet propulsion fuel 8. The fuel is delivered to the power plant by the supported unit or is arranged by the installation/base operating support. The consumption rate depends on the size and electrical load of the plant.

A-30. The time and cost required to deploy Army prime power assets into a theater of operation varies with the location and the priority of the mission. To ensure the rapid deployment of prime power assets, the requesting unit assigns a unit line number that references the force tracking number in the Joint Operation Planning and Execution System.

PRIME POWER SUPPORT TO EMERGENCY SUPPORT FUNCTION #3

A-31. The 249th Engineer Battalion supports the Emergency Support Function 3 (ESF#3)—the Public Works and Engineering Annex—of the National Response Framework. The battalion provides personnel and equipment based on ESF#3 requirements. The speed of deployment for personnel and equipment is driven by the priority and availability of transportation.

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Appendix B

Navy Electrical Power Capability

B-1. The Navy executes power generation and distribution as part of the mobile utilities support equipment (MUSE) program. The Navy also includes Navy construction engineer (Seabee) electricians, who perform tasks in a similar manner as those of Army interior electricians. The Navy operational concept of distributed maritime operations relies upon shore-based and sea-based networks of support facilities. Shore-based facilities include advanced naval bases in partner nation locations that may become damaged by enemy attacks or may be insufficient to meet Navy requirements for shore power and port services. The MUSE program provides the capability to address Navy shore-based power requirements.

B-2. The MUSE program—including 57 highly skilled, enlisted Seabee technicians—provides specialized utility equipment for the temporary support of utility and critical power systems, technical assistance, and training. MUSE includes power generation, transformation, and distribution for meeting emergencies and unforeseen utility shortfalls. The Department of the Navy provides MUSE to meet the requirements of federal and nonfederal activities in the five core areas listed in paragraph B-4.

B-3. The Naval Facilities Engineering Systems Command Expeditionary Warfare Center provides, commands, and executes the MUSE program in support of the Naval Facilities Engineering Systems Command public works. MUSE is intended as an interim solution to a long-term requirement, providing temporary utility support until permanent solutions are planned and programmed.

B-4. MUSE maintains an inventory of about 235 power generation, transformation, and distribution assets. These assets range from power plants with capacities from 800 kW to 2,500 kW (50 or 60 hertz) at voltages from 480 volts to 4,160 volts. Substations range from 2,500 to 18,000 kilovolt-amperes, 480 volts to 5 kilovolts and 15 kilovolts. Distribution equipment includes 1,200-ampere, 15-kilovolt automatic transfer switches to 5,000-ampere, 480-volt distribution systems. The MUSE units are designed with mobility in mind, and most are packaged into typical international standards organization containers for support of the following areas:

- **As directed by higher authority.** Support for other short-term requirements of federal and nonfederal activities, as directed by the Secretary of the Navy, Office of the Secretary of Defense, or the Joint Chiefs of Staff.
- **Cold iron.** Direct utility support for Navy vessels and fleet operations when the capacity of in-place services is insufficient or is nonexistent or uneconomical.
- **Contingency response, humanitarian assistance, and disaster relief.** Support of shore installations during unforeseen utility emergencies (failures resulting from natural disasters and unexpected equipment breakdowns) while interim repair or replacement of failed utilities or distribution is performed.
- **Expeditionary.** Support to expeditionary military operations, as required.
- **Facility.** Direct support of shore installations where in-place utility infrastructure is unable to meet system demands due to temporary overloads, increases in mission tempo, or changes to facility planning and programming until utility requirements are satisfied through normal programming.

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Appendix C
Air Force Electrical Power Capability

C-1. The electrical power capability of the Air Force is comprised of medium-voltage power generation and distribution equipment, as well as tactical generators. The Air Force uses the same medium-voltage equipment as the 249th Engineer Battalion (Prime Power) of the Army. The Air Force employs interior and exterior electrical skills separately, and power generation is separate from power distribution.

C-2. Air Force electrical systems technicians deploy as part of prime base expeditionary engineer force (Prime BEEF) or rapid engineer deployable heavy operational repair squadron engineer (RED HORSE) teams to execute large construction projects. These technicians perform or accomplish the following tasks in support of electrical systems:

- Install additional power feeds to temporary and permanent facilities and secondary distribution system components under field conditions.
- Install and maintain emergency airfield lights.
- Install, maintain, and repair all associated electrical components in secondary distribution systems, expeditionary and in-garrison facilities, 4,160 VAC electrical equipment, and other basic expeditionary airfield resources equipment; plan and develop primary and secondary electrical distribution layouts for expeditionary locations to support over 12 megawatts.
- Install, maintain, and repair distribution transformers, current regulators, oil circuit breakers, insulators, switching gear, and control circuits.
- Install, maintain, plan, and repair electrical distribution systems, lighting, circuit breakers, and equipment for real property-installed equipment and field-deployed facilities.
- Install, maintain, and repair grounding and lightning protection systems; modify and substitute foreign electrical components (breakers and receptacles) to suit local installation and field requirements.
- Install, maintain, and repair outside lighting, street lighting, and security lighting; maintain and repair visual navigational aids (runway lights and visual approach slope indicators) and assemble and install contingency airfield lighting and associated equipment.
- Maintain and repair overhead, underground, and temporary aboveground distribution systems to include cables, potheads, transformers, cable boxes, oil fuse cutouts, load limiters, controls, and instruments.

C-3. Air Force electrical power production technicians deploy as part of Prime BEEF or RED HORSE teams to complete large construction projects. These technicians perform or accomplish the following tasks in support of electrical power production:

- Apply power generation distribution constraints, control system logic, advanced troubleshooting, and field-level calibration on equipment.
- Install, maintain, operate, and certify a variety of aircraft arresting systems and components, including expedient installation of the mobile aircraft arresting system.
- Install, maintain, and repair a variety of commercial name-brand generators used as emergency backup and prime power.
- Install, maintain, and repair a variety of unmanned emergency electrical generators (diesel or gasoline) and components that support combat operations and combat support facilities.

- Maintain power generation systems, power-starting units, switchgears, fuel systems, and cooling systems; install, operate, and maintain automatic and manual power transfer systems.
- Operate and maintain prime power production facility equipment and standby power plant equipment.
- Perform emergency repair for generators and expediently connect power cables to power distribution systems and transfer switches.
- Plan power plant layouts and load analyses and install, operate, maintain, and repair associated power production components in base expeditionary airfield resource packages, including prime power generators and tactical generators.

C-4. Prime BEEF or RED HORSE employ electrical systems technicians to perform field-level maintenance for generators. Sustainment-level maintenance is performed by specialized civil engineer maintenance inspection repair teams or by depot level maintenance activity. Civil engineer maintenance inspection repair teams are composed of specially trained heating, ventilation, and air-conditioning technicians.

Appendix D
Marine Corps Electrical Power Capability

MARINE CORPS SUPPORT TO MILITARY OPERATIONS

D-1. Marine Corps Force Design 2030 requires the realignment of the Fleet Marine Force (FMF) structure; modernized equipment; and new tactics, techniques, and procedures for conducting expeditionary advanced base (EAB) operations. Operating from expeditionary advanced bases or advanced naval bases, FMF units support naval fleets during distributed maritime operations to accomplish sea control and sea denial missions. Deliberate experimentation tests new FMF organizational constructs; capabilities; and tactics, techniques, and procedures to—

- Refine Marine Corps force design by 2030.
- Enable expeditionary advanced base operations.
- Support naval fleets during distributed maritime operations.

See Tentative Manual for Expeditionary Advanced Base Operations for descriptions of new organizations.

D-2. Utility units in the FMF are manned, trained, and equipped to deliver tactical power generation and distribution to support missions across the competition continuum. These utility units are organized under, and designed to support, internal MAGTF requirements. They are uniquely poised for integrating with local utilities infrastructure, providing low-voltage electrical construction, and facilitating intelligence collection requirements. Most Marine Corps units possess utilities personnel and equipment to meet internal unit requirements for tactical electrical power. The MAGTF includes four elements: the logistics combat element, the aviation combat element, the command element, and the ground combat element. Under certain tactical circumstances, the MAGTF may receive an element from the naval construction force or Seabees, such as the naval mobile construction battalion. Utilities support organizations within each Marine expeditionary force size MAGTF include the engineer support battalion and the Marine wing support squadrons (MWSSs) of the Marine aircraft wing. The Marine logistics group engineer support battalion and the MWSS are typically designated to provide direct support to the regimental landing team or Marine aircraft group (MAG), respectively. The engineer support battalion is employed to provide general support across a Marine expeditionary force or Marine expeditionary brigade size MAGTF. The Marine expeditionary unit is the smallest permanently organized MAGTF. The Marine expeditionary unit logistics combat element consists of a single combat logistics battalion. The combat logistics battalion contains a reinforced engineer platoon, which contains a utilities section. The engineer platoon provides general support general engineering to the entire Marine expeditionary unit. See MCRP 1-10.1 for a more comprehensive description of the approved Marine Corps force structure.

D-3. As with the MAGTF, Marine Corps power generation and distribution support is scalable to the level of activity, threat condition, and mission. When conducting operations ashore at an expeditionary advance base, FMF utility units can independently serve with other FMF units. When operating at an advanced naval base, FMF utility units can work alongside Seabees that are supporting naval activities essential to the conduct of distributed maritime operations. For more information on Seabee capabilities, see NTTP 3-10.1M/MCWP 4-11.5.

ENGINEER SUPPORT BATTALION

D-4. The engineer support battalion provides general support and general engineering to a Marine expeditionary force or Marine expeditionary brigade size MAGTF. The engineer support battalion contains the personnel, equipment, and C2 mechanisms necessary to provide utilities support to the MAGTF. The engineer support battalion utility capability resides with the utilities platoon of the engineer support company.

MARINE WING SUPPORT SQUADRON

D-5. The MWSS is organized to provide aviation ground support directly to a MAG if the MAG is operating in garrison or as a composite MAG or MAGTF aviation combat element while deployed. Aviation ground support includes engineer services (power generation and distribution). The primary purpose of the MWSS is to sustain the operational tempo in terms of sortie generation for the supported MAG and attached elements of the Marine air control group. Core competencies of the MWSS encompass power generation and distribution to address personnel, aviation maintenance, expeditionary rescue and firefighting, and C2. The MWSS engineer company contains a utilities platoon that provides power generation and distribution, refrigeration and air conditioning, field showers, and laundry support to the MAG or aviation combat element. Elements of the Marine air control group possess the organic power generation equipment necessary to directly operate C2 centers, radar, navigation aids, and air traffic control systems. Likewise, the Marine aviation logistics squadron possesses organic power generation equipment that directly supports the maintenance of aviation and avionics systems.

COMBAT ENGINEER BATTALION

D-6. The Marine division receives organic power generation and distribution support from the combat engineer battalion. The combat engineer battalion possesses a single utilities platoon in the engineer support company. The platoon is capable of providing power generation and distribution support to support C2 of a Marine division.

MARINE AIR-GROUND TASK FORCE ELECTRICAL POWER GENERATION AND DISTRIBUTION EQUIPMENT

D-7. MAGTF power generation equipment consists of military standard power generators producing 120, 208, 240, and 416 VAC and outputs ranging from 1 kW to 60 kW. These generators are capable of producing a frequency of 50 or 60 hertz. Sometimes, power generation is accomplished through the use of COTS generators and alternative energy systems.

D-8. MAGTF power distribution equipment consists of military standard power distribution equipment ranging in size from 30 amperes to 1,200 amperes. The MEPDIS-R system is the preferred means of the Marine Corps for safely and effectively distributing power in a field and expeditionary environment. Sometimes power distribution is accomplished through the use of energy storage units, COTS distribution panels, and wiring.

MARINE AIR-GROUND TASK FORCE POWER GENERATION AND DISTRIBUTION PERSONNEL

D-9. Typically, the TO&E for MAGTF utility units includes restricted officers and enlisted personnel who are trained to plan, install, maintain, and repair power generation and distribution equipment. These Marines receive advanced specialized training in the planning of small- to large-scale tactical power grids, including heating, air conditioning, and refrigeration support; water purification equipment; hygiene equipment; bulk water production; storage and distribution equipment; and general supply equipment through the use of the stubby-pencil method and the electronic planning tool AutoDISE. They are also trained in the establishment of field maintenance areas to perform PMCS and corrective maintenance at various levels for power generation and distribution equipment. Specific skills, duties, and responsibilities for officers and enlisted MOSs include—

- **Utilities officer (MOS 1120).** Utilities officers are technical advisers to commanders at all levels of all elements of the various MAGTFs with regard to the timely and appropriate employment of utilities support. These warrant officers analyze, translate, and execute the commander's operational requirements into a utilities support reality that enhances mission accomplishment.

These individuals also plan, manage, delegate, and supervise the operation and maintenance of water purification, storage, and distribution sites; electrical power generation sites with inherent underground, aboveground, overhead, and tactical electrical power distribution systems; and shower and laundry services. These individuals coordinate and manage the installation, maintenance, and repair of heating, ventilation, air conditioning (including automotive), and refrigeration equipment. These individuals also coordinate and manage the maintenance and repair of the electrical systems on engineer and general supply equipment. Water quality assurance, field sanitation, sewage, and waste disposal are also planned, coordinated, and managed. When deployed in support of humanitarian assistance and civil-military operations, these officers plan, direct, and coordinate the installation and repair of plumbing and interior electrical systems. As Marine Corps utilities specialists, these individuals liaison with the Project Manager–Expeditionary Energy Sustainment Systems and Joint Water Resources Management Action Group to provide technical input regarding Marine Corps utilities requirements.

- **Electrician (MOS 1141).** Electricians plan, design, install, operate, maintain, and repair underground, aboveground, and tactical electrical power distribution systems. These individuals also perform PMCS and operate electrical power generation and power distribution equipment, load banks, and floodlight sets. In addition, electricians plan, design, install, and repair interior wiring according to the Unified Facilities Criteria, National Electrical Code, and local code requirements.
- **Engineer equipment electrical systems technician (MOS 1142).** Engineer equipment electrical systems technicians troubleshoot and repair the electrical circuits and systems of all engineer equipment (and some general supply equipment) at organizational and field levels of maintenance. These technicians are trained on electrical theory; solid-state device and power supplies; use and care of test, measurement, and diagnostic equipment; troubleshooting techniques; and reading and analyzing electrical schematics and wiring diagrams. The primary duty of engineer equipment electrical systems technicians is to diagnose and repair electrical circuits; the secondary duty is to diagnose, repair, and replace engine ancillary components (electrical starters and alternators). Repairs include soldering connections, replacing wires, and exchanging individual components of electrical circuits and circuit boards; repairing or replacing malfunctioning electrical motors, electrical modules, and other electrical components; and repairing or replacing faulty engine mechanical parts on engineer equipment.
- **Utilities chief (MOS 1169).** In the absence of the utilities officer, the utilities chief advises the commander on matters pertaining to utilities capabilities and their employment. The utilities chief also supervise planning and training and coordinates the installation, operation, and maintenance of utilities equipment. This MOS is technical in nature and requires years of experience to become proficient. Due to the diversity of commands throughout the Marine Corps, some of the duties and tasks performed by the utilities chief may overlap with those of the engineer equipment chief, motor transport maintenance chief, and motor transport operations chief MOSs. A senior utilities chief is assigned as a staff member of a MAGTF command element, ground combat element, aviation combat element, or logistics combat element to provide an enhanced knowledge base in the support of utilities planning efforts. This MOS is only assigned to graduates of the Marine Corps Engineer School resident Utilities Chief Course.

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Appendix E

Power Systems Equipment

ELECTRICAL POWER

E-1. Electrical power is an essential element of military operations. Without it, many crucial systems are unable to operate. C2 functions are highly reliant on continuous electrical power. Administrative, health service support, and logistical support operations are jeopardized without it. Also, many weapons systems are dependent on electrical power for operation. The proliferation of computers, sensors, and decision support tools has caused exponential growth in the electrical power needed to C2 the execution of all military operations. This growing dependence on electricity causes an increased requirement for quantity and quality of power for support operations. The indispensable nature of electrical power compels commanders and planners to recognize and ensure that electrical power needs are met.

SOLDIER POWER PROGRAM SETS

E-2. Soldier power program sources are portable and can provide up to 3 kW of power. The power source currently used is the 2-kW tactical generator (see figure E-1). It is portable, skid-mounted, jet propulsion 8-fueled, AC (60 hertz), and direct current (28 volts direct current). The 3-kW tactical quiet generator (see figure E-2, page E-2) is skid-mounted and diesel-fueled (60 hertz and 400 hertz).

Figure E-1. 2-kW tactical generator

TACTICAL ELECTRICAL POWER

E-3. Tactical electrical power is generated by mobile electrical power sources dedicated to supporting the missions of units engaged in combat operations. To reduce logistics support, DOD created a DOD standard family of mobile electrical power sources for use by all Services. The listing of sources and technical characteristics of this family are provided in MIL-STD-633G. These standard military generators are highly mobile, produce user voltages (120/208 volt, or 240/416 volt at 60 Hz and 230/400 at 50 Hz), do not require the use of transformers, and have an output capacity ranging from 2 kW to 500 kW. Standard military generators are in the unit TO&E and are referred to as “tactical generators.” The Army uses PDISE for electrical distribution, while the Marine Corps uses MEPDIS-R. The installation, operation, and maintenance of tactical generators and distribution equipment are the responsibility of the unit using the equipment.

Figure E-2. 3-kW tactical quiet generator

ADVANCED MEDIUM MOBILE POWER SOURCE

E-4. The AMMPS is a program of record for all Services (see figure E-3). AMMPS represents the third generation of the DOD standard family of mobile electrical power sources in the 5–60 kW power range. AMMPS replaces the mobile electrical power tactical quiet generator series. AMMPS provides operational improvements that decrease the logistics footprint. The current family of AMMPS consists of trailer- and skid-mounted models that are 5 kW, 10 kW, 15 kW, 30 kW, or 60 kW.

E-5. The AAMPS generators of the Marine Corps have the Advanced Digital Control System (ADCS) for generators of the 5–60 kW size. The ADCS provides an intelligent microgrid capability that automatically matches power production to load demand, provides an auto-start capability for future hybrid/energy systems, and increases generator efficiency (reducing fuel consumption and wear on the generators).

Note: “Medium” refers to the power output capacity, not the voltage.

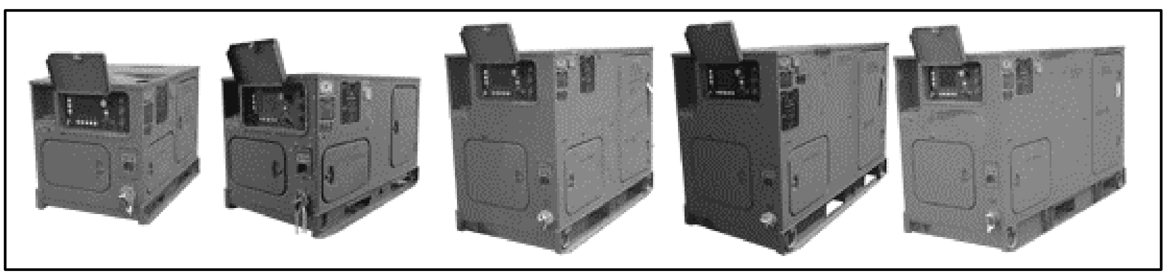

Figure E-3. AMMPS

POWER UNITS AND POWER PLANTS

E-6. AMMPS can be configured as trailer-mounted power units and power plants. Power units consist of a single generator set mounted on a trailer. Power plants consist of two generator sets mounted on a single trailer or on two trailers, with a switch box for providing redundant power. The power units and power plants are mounted on military standard trailers matched to their required prime movers. High-mobility, multiple-wheel vehicle configurations use light tactical trailers, whereas larger vehicles (the family of medium tactical vehicles) use large semitrailers to move larger loads with more stability. The power unit and power plant configurations are described in MIL-STD-633G. Figure E-4 depicts the current AMMPS power systems.

Figure E-4. AMMPS power systems

LARGE MOBILE POWER SOURCES

E-7. Large mobile power sources have outputs between 100 to 500 kW. These systems are modernized, technologically advanced, tactically quiet, diesel-fueled, lightweight, reliable, and rugged. Large mobile power sources can be employed as skid-mounted or trailer-mounted (power unit) configurations. Figure E-5 depicts the systems in skid-mounted and power unit configurations.

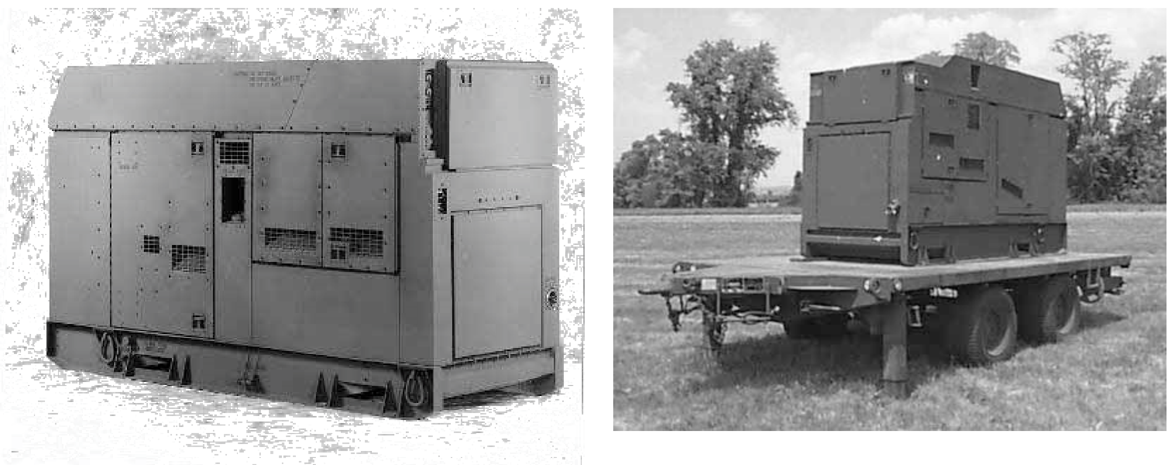

Figure E-5. Large power sources

TACTICAL POWER DISTRIBUTION

E-8. Tactical power distribution is accomplished through the PDISE system (Army) and the MEPDIS-R system (Marine Corps). The PDISE and MEPDIS-R provide portable, reliable, modular, quick-assembly, standardized electrical distribution systems. These systems allow individuals to connect generators to multiple loads and to construct microgrids. These systems are designed to work with any of the DOD standard family of mobile electrical power sources that generate 5 kW or more of electricity. See figure E-6, page E-4, for examples of PDISE and MEPDIS-R equipment. PDISE and MEPDIS-R are not directly compatible—but there are adapters available to connect the two. There are two similar connectors to connect PDISE to the MEPDIS-R that can be obtained using the national stock number (NSN) 6150-01-529-7698 (female 100 ampere) or 6150-01-529-8063 (female 60 ampere). In addition, the connector needed to go from the MEPDIS-R to PDISE can be ordered using NSN 6150-01-529-8424 (male 100 ampere) or NSN 6150-01-529-7908 (male 60 ampere). All Marine Corps connections make use of blue and grey-colored plastic ring connectors.

Figure E-6. Tactical power distribution systems

PRIME POWER

E-9. Military prime power is produced in the Army by the MEP-810 prime power unit (figure E-7). The prime power plants produce medium-voltage (4,160 volts) and employ a distribution system with transformers to reduce the voltage to user voltages (120/208 volt or 277/480 volt at 60 Hz and 230/400 at 50 Hz). The MEP-810 may be deployed in multiple-unit power plant configurations for increased output capacities. Site preparation may be required for prime power generator installation. In the Air Force, the prime power system is the named the base expeditionary airfield resources (BEAR) generator (MEP-810).

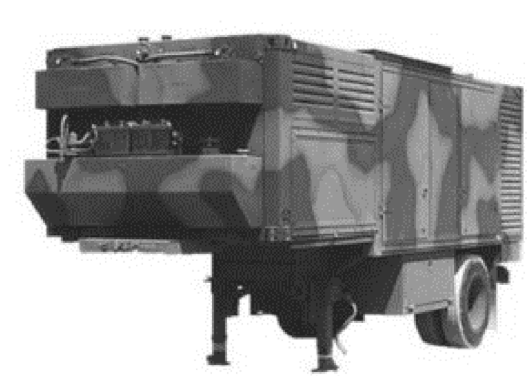

Figure E-7. MEP-810

E-10. Prime power generator sets are in the medium-voltage range and require the use of switchgear-, transformer-, and medium-voltage-rated cabling to distribute electricity. Prime power generation systems may be employed as stand-alone power sources (isolated load) or in parallel with commercial power sources (load-sharing or peak-shaving modes). The installation, operation, maintenance, and repair of prime power assets are the responsibility of engineer prime power units.

PRIME POWER DISTRIBUTION

E-11. The medium-voltage primary switch center (see figure E-8) is the main point of connection from generator to generator and from generator to distribution cables. On larger and more complex distribution networks, this primary switch center is used in loop designs and connects the SDCs.

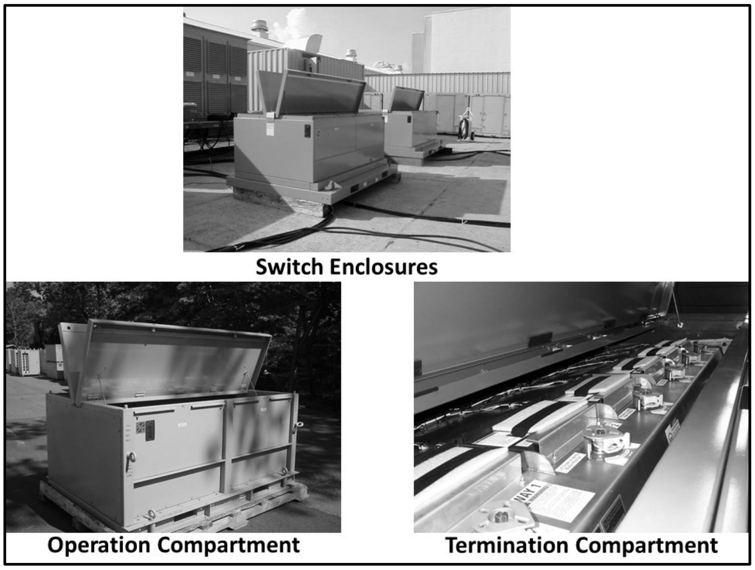

Figure E-8. Primary switch center

E-12. The SDC features a 150 kilovolt-ampere, three-phase 2,400/4,160 VAC primary, 120/208 VAC secondary utility transformer and a low-voltage secondary distribution panel (figure E-9). The SDC is compatible with PDISE.

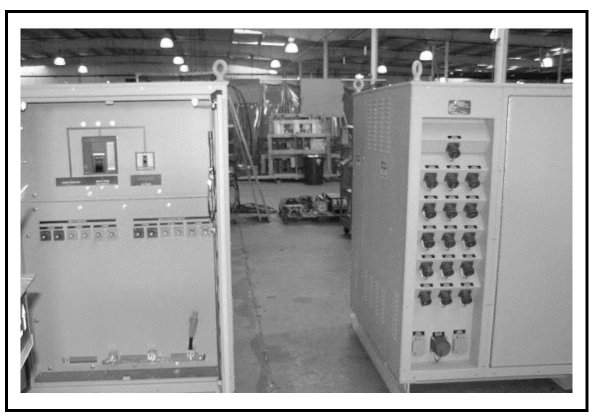

Figure E-9. Secondary distribution center

PREDESIGNED BASE CAMP

E-13. Air Force BEAR unit codes are aggregated into sets or packages that provide environmental control unit capabilities. Sets may be further broken down into subunit codes or involve less than full-set deployments. BEAR base equipment allowance standards are found in Air Force system 157 (BEAR); Air Force system 158 (Harvest Falcon); Air Force system 159 (Harvest Eagle); and Air Force system 429, Part N, for training assets. For a more detailed description of the set contents, refer to AFH 10-222, Volume 2.

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Appendix F

Electrical Inspection Process

F-1. All electrical wiring is inspected to ensure compliance with established standards. The National Fire Protection Agency continuously reviews and updates the National Electric Code (NEC) on a 3-year basis. The regulatory board of the National Fire Protection Agency is comprised of industry professionals who encompass all facets and environments of the petrochemical industry, commercial construction, residential construction, industrial construction, and even the temporary facilities that make up fairs and circuses. In the United States, the NEC is the accepted standard for electrical construction and installations. Within the DOD, there are various Unified Facilities Criteria and specifications that mirror the NEC. However, all certified electrical journey workers and master electricians take tests that ensure their understanding of the NEC and how to properly use it to perform their tasks. The NEC specifies how qualified electrical workers construct, install, operate, and, at times, maintain electrical systems.

F-2. Systems that permit and grant the occupancy of facilities (including temporary installations) have been developed throughout the United States and the rest of the developed world to ensure the safety of the general public, personnel, equipment, and facilities. Electrical inspectors are critical to those processes.

F-3. During combat operations, the DSCA, and Humanitarian Assistance and Disaster Relief, electricity is extremely critical to the mission, shaping the battlefield and saving lives. The need to install power systems in a quick, safe, and efficient manner is often affected by resource constraints and mission priorities. At times, this results in electrical systems and construction that do not meet industry standards for even temporary installation within the NEC or guidelines set forth in field manuals, technical manuals, or Unified Facilities Criteria. Deviations from standard construction practices are authorized by commanders on the ground using information provided by technical representatives. It This ensures the authority of command when decisions are made, which places the mission above some electrical industry standard safety measures.

F-4. The NEC allows deviations in electrical installations when an authority that has jurisdiction can determine a safe alternative. The authority that has jurisdiction is an independent individual or entity with a vast amount of experience and training and the appropriate certifications. The individual or entity is usually appointed by a governmental agency and is serving in an independent role to ensure that proper checks and balances are in place in the electrical installation process. The authority that has jurisdiction publishes guidance on deviations from the NEC, as well as clarifications of the NEC applied to the areas that they oversee. An electrical inspector may act as an authority who has jurisdiction when appointed as such. However, a senior authority with jurisdiction typically provides guidance for most electrical inspectors. The authority having jurisdiction should not be an organization that would benefit or profit from the installations and processes being overseen.

F-5. Improper electrical installations degrade missions, present hazards to personnel, and become costly over time. The use of Logistics Civil Augmentation Program for construction and maintenance, the role of the Directorate of Public Works, and the base camp commander/base operating support-integrator are critical to the operations and maintenance of facilities, systems, and infrastructure during all phases of operations. If generators that are installed, facilities that are constructed, and/or systems that are erected do not meet NEC or other regulatory standards, they cannot be legally maintained by the agencies that are designed to maintain them. Imagine a commander in a contingency operation relying on a naval construction regiment, a theater engineer command, or a contractor for the construction of a headquarters building or berthing for the Service members in their charge. If the constructing organization were to cut corners during construction to meet timelines and inspections were not completed, the base camp commander/base operating support-integrator would be unaware that the facility was improperly constructed and may be unsafe for occupancy. Under the same conditions, Logistics Civil Augmentation Program or the Directorate of Public Works would discover the improperly installed electrical wire/equipment when the facility acceptance inspection was conducted (prior to assuming responsibilities for the operations and maintenance of the facility).

F-6. The electrical inspection process consists of the following key phases:

- **Review of print and acceptance of design (even for temporary installations).** This phase consists of the authority that has jurisdiction or the electrical inspector reviewing the prints and/or plans. The authority/inspector ensures that load calculations are completed and accurate, that the general workmanship is satisfactory, and that there is an engineering stamp or equivalent approval. Design acceptance is completed, regardless of the system or facility. Panel schedules are properly identified. Proper wire sizes and overcurrent protection are determined. These set the requirements for electrical inspection criteria in the field.
- **Issuance of a building permit.** The next phase of the inspection process consists of the release of approved plans by the authority that has jurisdiction or a demonstration by the electrical inspector that the plans are approved, and a notice to proceed or a construction permit (including temporary installations) is issued. This permit includes a checklist for the inspector to sign for each phase of the outlined inspection process. If an inspector finds deficiencies or issues during any phase of the construction process, he or she outlines the exact problem, provides NEC guidance and the exact NEC code that was violated, and works with the installing agency to complete a reinspection of the failed area. It is common practice for inspectors to place red inspection tags on the device, system or area that fails the inspection. Green tags are issued for each phase that passes inspection.
- **Beginning of construction or installation.** During this phase, the responsible individual or organization that will be performing the work develops a project timeline to ensure that future inspections are scheduled and adhered to prior to moving to the next phase of electrical construction. It is common practice for an electrical inspector to stop work if phases of the inspection process are skipped. If an inspector is unable to verify the actual installation during each phase of the process, the area of concern is deconstructed, uncovered, or otherwise altered to allow the inspector to ensure adherence to the NEC and to ensure that the approved plans for the project have been met. During this phase, a temporary electrical system may need to be established. This system is subject to inspection by the electrical inspector as well and should be included in the original design prints or plans.
- **Underground inspections.** Underground inspections are performed to ensure that conduits and/or cables are buried to the proper depth in accordance with NEC or the construction prints (whichever is more stringent). The inspector ensures that proper backfill is utilized and that cables and conduit systems are properly installed in accordance with trade practice. The inspector signs off on the appropriate paperwork at the completion of the underground inspection, allowing the project to continue to the next phase.
- **Unscheduled inspections.** Throughout the project, the electrical inspector may show up at the project site unannounced and inspect key items in relation to the electrical systems. Each unscheduled inspection is recorded, and the records contain a description of what was inspected.
- **Rough-in inspections.** A rough-in inspection is one in which the inspector reviews the wiring prior to the installation of sheetrock, cement board, plywood, or any other wall covering. The inspector checks for proper equipment spacing, wire sizes, box fill, conduit fill, methods used to support conductors, and any other areas specified by the NEC. Once the inspector approves of the work completed during this phase, the wall coverings may be installed. As with any phase of the inspection process, if there are discrepancies, work is stopped until corrections are made and the inspector verifies the work to allow the project to continue.
- **Device inspections**. Once all devices are wired, and prior to the final installation in their boxes, a device inspection is completed. The electrical inspector verifies that the devices are manufactured and certified by an accepted listing agency, rated for use in the area in which they are installed, match what was outlined in the approved plans, and have been installed in a workmanlike manner. Upon receiving the approval from the inspector, the devices are allowed to be installed in the boxes that they are designated to be installed in, but the covers must remain off until the final inspection.

- **Panel inspections**. The panel inspection is critical to the safety of personnel, the facility, and all equipment that receives power from the electrical system being installed. The electrical inspector ensures that a proper grounding electrode system is installed in accordance with NEC. The inspector verifies the size of the main grounded and ungrounded conductors. The inspector also verifies that the overcurrent protection is properly sized in accordance with the approved plans and NEC. The grounding system is tested to ensure that NEC requirements are met. If any ground fault circuit interrupters or arc fault circuit interrupters are required, the inspector ensures the interrupters are installed correctly and are rated for use. If the inspector approves of this phase of the project, authorization for the electricians to install the covers on all of the devices as long as the other tradespersons are finished with the phases of the project that require them to remain off.
- Any items, areas, or tasks that did not meet standard are reinspected.
- **Final inspections.** Once the system or facility is ready for a final inspection, the appropriate coordination is made to ensure that the inspector can verify that all items can be properly operated. Operation of backup power systems is verified. If required, all emergency lighting and exit lights are verified to ensure that they are operational with and without power. All device covers should be in place at the time of the inspection. The inspector verifies that outlets are wired correctly. One of the most important steps in this phase is ensuring that all circuits are properly labeled. At the end of this phase of the inspection, the inspector issues the final inspection approval paperwork and closes out the electrical construction permit. If any changes to the facility are made or future construction is planned, a new set of prints or plans is developed and the permit process for the project is repeated.
- **Granting of occupancy**. The granting of occupancy of a structure is not limited to just the electrical inspection; plumbing, mechanical, and structural inspections as well as inspections for any other trades involved in the process will also likely be required. Most importantly, the local fire marshal (or equivalent agency) must sign off on the paperwork granting occupancy.

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Appendix G
Electrical Safety

POWER PRODUCTION DURING DEPLOYMENTS

G-1. The presence of electricity on the battlefield is not new. As technology changes, the need for power generation during deployments grows. While electricity is a force enabler, its generation and distribution carries risks—especially regarding electrical safety. In accordance with AR 385-10 only personnel who have been formally trained should perform power generation and distribution tasks. This is especially important for damaged or nonstandard systems.

G-2. This section addresses best practices but recognizes that conditions, which are rarely optimal, differ throughout the battlefield; that military personnel quickly must adapt to changes in battlefield conditions; and that it is not always immediately possible to follow best practices. Examples of the conditions that vary range from the ground/soil to the speed of power production installation to the availability of personnel or resources. In these circumstances, electrical systems should be installed as safely as possible and then improved as soon as possible, given the conditions.

ELECTRICAL SHOCK AND ARC BLAST

G-3. Electricity always attempts to return to the source, which could be a generator, battery, solar panel, service panel, or receptacle. The conductors (wires) within an electrical system are described as positive/hot, negative/neutral, or grounding. The number of conductors vary from system to system (single-phase versus three-phase versus DC), and the color coding varies based on the source type (AC versus DC), system voltage, and country of origin. Manufacturers are not required to follow color convention if the equipment is enclosed. In normal operation, the positive and negative wires are separated by an electrical load (pump, motor, or communications system). In general, electrical flow can be described as originating at the positive terminal(s) of the source and then traveling through the positive conductor(s), the load, and the negative conductor(s); and then returning to the source. This flow represents a current path. Electrical systems can have simple or complex current paths.

G-4. Like the fluid dynamics of water, electricity takes all paths. Electrical shock occurs when a person encounters electricity (through direct or indirect means) and becomes an alternate path for current flow. The results of electrical shock vary; depending on the amount of energy available, through a variety of variables. For example, a car battery has more available energy than an AA battery. These results can be as mild as no effect to a tingle or as severe as burnt skin and/or cardiac arrest.

G-5. Arc blast occurs when a positive conductor comes in contact (through direct or indirect means) with another conductor (positive, neutral, or ground) and the energy released causes an explosion. This explosion can expand 67,000 times the original volume and reach temperatures of 35,000ºF—resulting in the ability to vaporize metal. The blast continues until a safety device fuse or circuit breaker is tripped; conductor, object, and/or person is disintegrated or removed from the electrical path; and/or all energy is expended (which is very rare). An arc blast can cause personal injury and equipment damage. The level of damage is dependent on the amount of energy available. Arc welding is an example of a controlled arc blast.

GROUNDING

G-6. In electrical systems, grounding is critical to protecting personnel and equipment. Grounding ensures that there is a path to the earth in the event of a ground fault condition. Ground faults can come from damage to the electrical system, environmental conditions, poor wiring practices, or faulty equipment. During operations in Iraq and Afghanistan, several fatalities and structure fires were caused by improper installation; inferior materials; and glossy, overloaded circuits.

G-7. Ground rods, conductors, and other grounding systems are installed in accordance with the appropriate technical manuals, codes, or theater standards. This work should be inspected upon initial installation and at regular intervals, depending on the on-ground conditions. Special attention should be given to grounding systems in wet areas such as latrines, showers, and kitchens.

MULTISOURCE AND HYBRID SYSTEMS

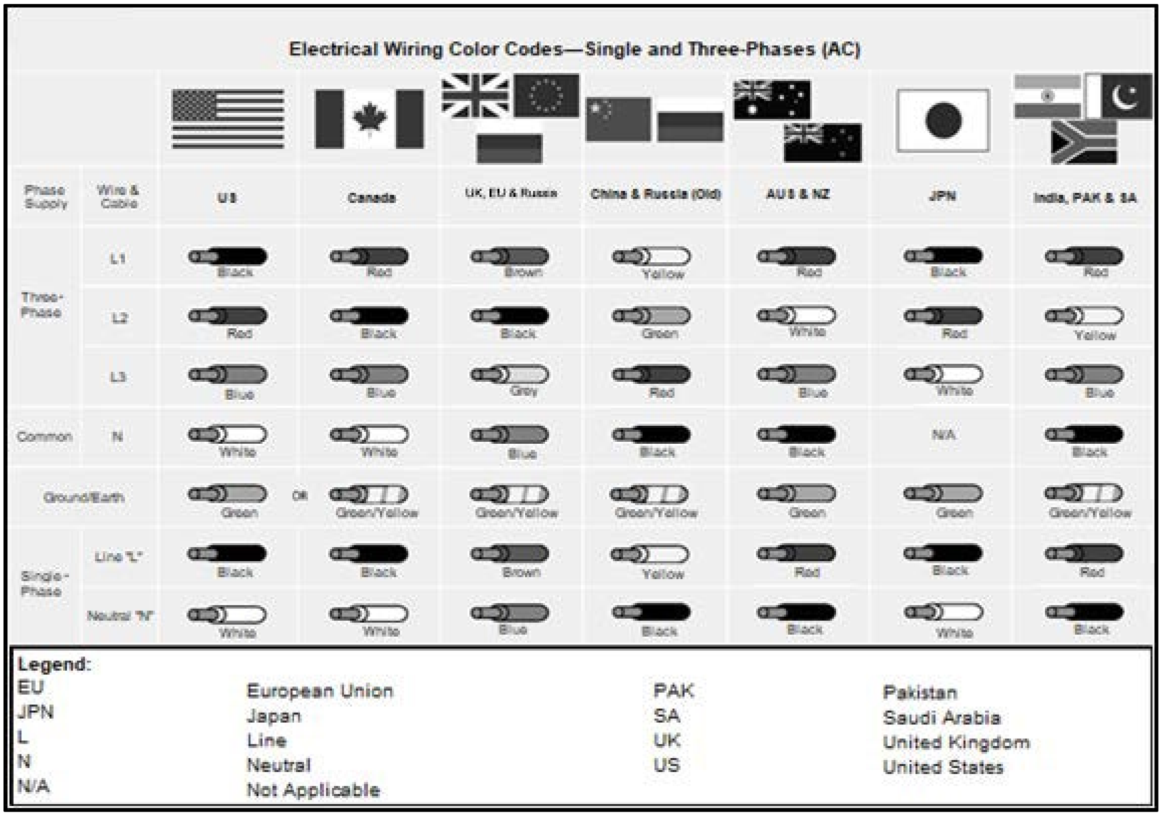
G-8. While single-source power systems pose a potential threat of electrical shock and arc blast, multisource and hybrid systems can pose an even greater threat to individuals tasked with operating and maintaining such systems. This is especially true for silent energy sources (battery and solar) because those systems do not audibly indicate when they are generating electricity. As a result, personnel operating and maintaining these systems may mistake an energized system for one that is not energized. To avoid this mistake, personnel ensure that all energy sources are identified and that proper precautions are taken to verify that the conductors have been de-energized prior to performing any maintenance or repair action.

Appendix H
International Interoperability

The U.S. military operates worldwide. This appendix contains information about the distribution of electricity worldwide, including nation-specific wiring codes for single and three-phase AC electricity, voltages, frequencies, and plug and outlet characteristics. Planners should consider this information when conducting exercises or during deployment planning.

WIRING COLOR CODES

H-1. Figure H-1, page H-2, illustrates nation-specific electrical wiring color codes for single and three-phase AC, utility-generated electricity. The wiring color codes for single and three-phase electricity determine phase rotation for the generator that is being used to produce the electricity. More importantly, the color codes are used to determine the physical connection of electrical cables (line, neutral, ground). Specific attention should be paid to the fact that the color for the neutral wire (single and three-phase) in several nations (China, Russia, Australia, New Zealand, India, Pakistan, Saudi Arabia) is black, whereas in the United States, the color black is used for an energized line (L or L1). A similar interoperability and safety concern applies when comparing the color codes for three-phase power between the United Kingdom and the United States. Blue-colored wiring is used for neutral (N) in the United Kingdom, whereas blue is used for an energized line (L3) in the United States.



Electrical Wiring Color Codes—Single and Three-Phases (AC)

Phase Supply	Wire & Cable	US	Canada	UK, EU & Russia	China & Russia (Old)	AUS & NZ	JPN	India, PAK & SA
Three-Phase	L1	Black	Red	Brown	Yellow	Red	Black	Red
	L2	Red	Black	Black	Green	White	Red	Yellow
	L3	Blue	Blue	Grey	Red	Blue	White	Blue
Common	N	White	White	Blue	Black	Black	N/A	Black
Ground/Earth		Green OR	Green/Yellow	Green/Yellow	Green/Yellow	Green	Green	Green/Yellow
Single-Phase	Line "L"	Black	Black	Brown	Yellow	Red	Black	Red
	Neutral "N"	White	White	Blue	Black	Black	White	Black

Legend:

EU	European Union	PAK	Pakistan
JPN	Japan	SA	Saudi Arabia
L	Line	UK	United Kingdom
N	Neutral	US	United States
N/A	Not Applicable		

Figure H-1. Electrical wiring color codes – 1 & 3 Phase (AC)

VOLTAGE, FREQUENCY, PLUGS, AND OUTLETS

H-2. Table H-1 depicts voltage, frequency, and plug and outlet characteristics by country/state/territory for single-phase, AC electricity. The table is aligned with the depictions of plugs and outlets that are assembled in figure H-2, page H-9.

Table H-1. Worldwide voltages

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2, page H-9)*
Abu Dhabi	230 V	50 Hz	G
Afghanistan	220 V	50 Hz	C/F
Albania	230 V	50 Hz	C/F
Algeria	230 V	50 Hz	C/F
American Samoa	120 V	60 Hz	A/B/F/I
Andorra	230 V	50 Hz	C/F
Angola	220 V	50 Hz	C
Anguilla	110 V	60 Hz	A/B
Antigua and Barbuda	230 V	60 Hz	A/B
Argentina	220 V	50 Hz	I
Armenia	230 V	50 Hz	C/F
Aruba	120 V	60 Hz	A/B/F
Australia	230 V	50 Hz	I

Table H-1. Worldwide voltages (continued)

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2)*
Austria	230 V	50 Hz	C/F
Azerbaijan	220 V	50 Hz	C/F
Azores	230 V	50 Hz	B/C/F
Bahamas	120 V	60 Hz	A/B
Bahrain	230 V	50 Hz	G
Balearic Islands	230 V	50 Hz	C/F
Bangladesh	220 V	50 Hz	A/C/D/G/K
Barbados	115 V	50 Hz	A/B
Belarus	220 V	50 Hz	C/F
Belgium	230 V	50 Hz	C/E
Belize	110 V/220 V	60 Hz	A/B/G
Benin	220 V	50 Hz	C/E
Bermuda	120 V	60 Hz	A/B
Bhutan	230 V	50 Hz	C/D/G
Bolivia	230 V	50 Hz	A/C
Bonaire	127 V	50 Hz	A/C
Bosnia and Herzegovina	230 V	50 Hz	C/F
Botswana	230 V	50 Hz	D/G
Brazil	127 V/220 V	60 Hz	C/N
British Virgin Islands	110 V	60 Hz	A/B
Brunei	240 V	50 Hz	G
Bulgaria	230 V	50 Hz	C/F
Burkina Faso	220 V	50 Hz	C/E
Burma (officially Myanmar)	230 V	50 Hz	A/C/D/G/I
Burundi	220 V	50 Hz	C/E
Cambodia	230 V	50 Hz	A/C/G
Cameroon	220 V	50 Hz	C/E
Canada	120 V	60 Hz	A/B
Canary Islands	230 V	50 Hz	C/E/F
Cape Verde	230 V	50 Hz	C/F
Cayman Islands	120 V	60 Hz	A/B
Central African Republic	220 V	50 Hz	C/E
Chad	220 V	50 Hz	C/D/E/F
Channel Islands (Guernsey and Jersey)	230 V	50 Hz	C/G
Chile	220 V	50 Hz	C/L
China, People's Republic of	220 V	50 Hz	A/C/I
Christmas Island	230 V	50 Hz	I
Cocos (Keeling) Islands	230 V	50 Hz	I
Colombia	110 V	60 Hz	A/B
Comoros	220 V	50 Hz	C/E
Congo, Democratic Republic of	220 V	50 Hz	C/D/E

Table H-1. Worldwide voltages (continued)

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2)*
Congo, People's Republic of	230 V	50 Hz	C/E
Cook Islands	240 V	50 Hz	I
Costa Rica	120 V	60 Hz	A/B
Côte d'Ivoire (Ivory Coast)	220 V	50 Hz	C/E
Croatia	230 V	50 Hz	C/F
Cuba	110 V/220 V	60 Hz	A/B/C/L
Curacao	127 V	50 Hz	A/B
Cyprus	230 V	50 Hz	G
Cyprus, North (unrecognized, self-declared state)	230 V	50 Hz	G
Czech Republic	230 V	50 Hz	C/E
Denmark	230 V	50 Hz	C/E/F/K
Djibouti	220 V	50 Hz	C/E
Dominica	230 V	50 Hz	D/G
Dominican Republic	120 V	60 Hz	A/B/C
Dubai	230 V	50 Hz	G
East Timor (Timor-Leste)	220 V	50 Hz	C/E/F/I
Ecuador	120 V	60 Hz	A/B
Egypt	220 V	50 Hz	C/F
El Salvador	120 V	60 Hz	A/B
England	230 V	50 Hz	G
Equatorial Guinea	220 V	50 Hz	C/E
Eritrea	230 V	50 Hz	C/L
Estonia	230 V	50 Hz	C/F
Ethiopia	220 V	50 Hz	C/F
Faeroe Islands	230 V	50 Hz	C/E/F/K
Falkland Islands	240 V	50 Hz	G
Fiji	240 V	50 Hz	I
Finland	230 V	50 Hz	C/F
France	230 V	50 Hz	C/E
French Guiana	220 V	50 Hz	C/D/E
Gabon (Gabonese Republic)	220 V	50 Hz	C
Gambia	230 V	50 Hz	G
Gaza Strip (Gaza)	230 V	50 Hz	C/H
Georgia	220 V	50 Hz	C/F
Germany	230 V	50 Hz	C/F
Ghana	230 V	50 Hz	D/G
Gibraltar	230 V	50 Hz	G
Great Britain	230 V	50 Hz	G
Greece	230 V	50 Hz	C/F
Greenland	230 V	50 Hz	C/E/F/K
Grenada	230 V	50 Hz	G

Table H-1. Worldwide voltages (continued)

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2)*
Guadeloupe	230 V	50 Hz	C/E
Guam	110 V	60 Hz	A/B
Guatemala	120 V	60 Hz	A/B
Guinea	220 V	50 Hz	C/F/K
Guinea-Bissau	220 V	50 Hz	C
Guyana	120 V/240 V	60 Hz	A/B/D/G
Haiti	110 V	60 Hz	A/B
Holland (officially the Netherlands)	230 V	50 Hz	C/F
Honduras	120 V	60 Hz	A/B
Hong Kong	220 V	50 Hz	G
Hungary	230 V	50 Hz	C/F
Iceland	230 V	50 Hz	C/F
India	230 V	50 Hz	C/D/M
Indonesia	230 V	50 Hz	C/F
Iran	230 V	50 Hz	C/F
Iraq	230 V	50 Hz	C/D/G
Ireland	230 V	50 Hz	G
Isle of Man	230 V	50 Hz	C/G
Israel	230 V	50 Hz	C/H
Italy	230 V	50 Hz	C/F/L
Jamaica	110 V	50 Hz	A/B
Japan	100 V	50 Hz/60 Hz	A/B
Jordan	230 V	50 Hz	C/D/F/G/J
Kazakhstan	220 V	50 Hz	C/F
Kenya	240 V	50 Hz	G
Kiribati	240 V	50 Hz	I
Korea, North	220 V	50 Hz	C
Korea, South	220 V	60 Hz	F
Kosovo	230 V	50 Hz	C/F
Kuwait	240 V	50 Hz	G
Kyrgyzstan	220 V	50 Hz	C/F
Laos	230 V	50 Hz	A/B/C/E/F
Latvia	230 V	50 Hz	C/F
Lebanon	230 V	50 Hz	C/D/G
Lesotho	220 V	50 Hz	M
Liberia	120 V	60 Hz	A/B
Libya	230 V	50 Hz	C/L
Liechtenstein	230 V	50 Hz	C/J
Lithuania	230 V	50 Hz	C/F
Luxembourg	230 V	50 Hz	C/F
Macau	220 V	50 Hz	G
Macedonia, Republic of (the former Yugoslav Republic of Macedonia)	230 V	50 Hz	C/F

Table H-1. Worldwide voltages (continued)

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2)*
Madagascar	220 V	50 Hz	C/E
Madeira	230 V	50 Hz	C/F
Malawi	230 V	50 Hz	G
Malaysia	240 V	50 Hz	G
Maldives	230 V	50 Hz	C/D/G/J/K/L
Mali	220 V	50 Hz	C/E
Malta	230 V	50 Hz	G
Marshall Islands	120 V	60 Hz	A/B
Martinique	220 V	50 Hz	C/D/E
Mauritania	220 V	50 Hz	C
Mauritius	230 V	50 Hz	C/G
Mayotte	230 V	50 Hz	C/E
Mexico	120 V	60 Hz	A/B
Micronesia, Federated States of	120 V	60 Hz	A/B
Moldova	230 V	50 Hz	C/F
Monaco	230 V	50 Hz	C/E/F
Mongolia	230 V	50 Hz	C/E
Montenegro	230 V	50 Hz	C/F
Montserrat	230 V	60 Hz	A/B
Morocco	220 V	50 Hz	C/E
Mozambique	220 V	50 Hz	C/F/M
Myanmar (formerly Burma)	230 V	50 Hz	A/C/D/G/I
Namibia	220 V	50 Hz	D/M
Nauru	240 V	50 Hz	I
Nepal	230 V	50 Hz	C/D/M
Netherlands	230 V	50 Hz	C/F
New Caledonia	220 V	50 Hz	C/F
New Zealand	230 V	50 Hz	I
Nicaragua	120 V	60 Hz	A/B
Niger	220 V	50 Hz	C/D/E/F
Nigeria	230 V	50 Hz	D/G
Niue	230 V	50 Hz	I
Norfolk Island	230 V	50 Hz	I
North Cyprus (unrecognized, self-declared state)	230 V	50 Hz	G
Northern Ireland	230 V	50 Hz	G
Norway	230 V	50 Hz	C/F
Oman	240 V	50 Hz	G
Pakistan	230 V	50 Hz	C/D
Palau	120 V	60 Hz	A/B
Palestine	230 V	50 Hz	C/H
Panama	120 V	60 Hz	A/B

Table H-1. Worldwide voltages (continued)

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2)*
Papua New Guinea	240 V	50 Hz	I
Paraguay	220 V	50 Hz	C
Peru	220 V	60 Hz	A/C
Philippines	220 V	60 Hz	A/B/C
Pitcairn Islands	230 V	50 Hz	I
Poland	230 V	50 Hz	C/E
Portugal	230 V	50 Hz	C/F
Puerto Rico	120 V	60 Hz	A/B
Qatar	240 V	50 Hz	G
Réunion	230 V	50 Hz	C/E
Romania	230 V	50 Hz	C/F
Russia (officially the Russian Federation)	220 V	50 Hz	C/F
Rwanda	230 V	50 Hz	C/J
Saba	110 V	60 Hz	A/B
Saint Barthélemy (informally also referred to as Saint Barth’s or Saint Barts)	230 V	60 Hz	C/E
Saint Kitts and Nevis (officially the Federation of Saint Christopher and Nevis)	230 V	60 Hz	D/G
Saint Lucia	230 V	50 Hz	G
Saint Martin	220 V	60 Hz	C/E
Saint Helena	230 V	50 Hz	G
Saint Vincent and the Grenadines	110 V/230 V	50 Hz	A/B/G
Samoa	230 V	50 Hz	I
San Marino	230 V	50 Hz	C/F/L
São Tomé and Príncipe	230 V	50 Hz	C/F
Saudi Arabia	230 V	60 Hz	G
Scotland	230 V	50 Hz	G
Senegal	230 V	50 Hz	C/D/E/K
Serbia	230 V	50 Hz	C/F
Seychelles	240 V	50 Hz	G
Sierra Leone	230 V	50 Hz	D/G
Singapore	230 V	50 Hz	G
Sint Eustatius	110 V/220 V	60 Hz	A/B/C/F
Sint Maarten	110 V	60 Hz	A/B
Slovakia	230 V	50 Hz	C/E
Slovenia	230 V	50 Hz	C/F
Solomon Islands	230 V	50 Hz	G/I
Somalia	220 V	50 Hz	C
Somaliland	220 V	50 Hz	C
South Africa	230 V	50 Hz	C/M/N

Table H-1. Worldwide voltages (continued)

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2)*
South Sudan	230 V	50 Hz	C/D
Spain	230 V	50 Hz	C/F
Sri Lanka	230 V	50 Hz	D/G
Sudan	230 V	50 Hz	C/D
Suriname	127 V/230 V	60 Hz	A/B/C/F
Swaziland	230 V	50 Hz	M
Sweden	230 V	50 Hz	C/F
Switzerland	230 V	50 Hz	C/J
Syria	220 V	50 Hz	C/E/L
Tahiti	220 V	50 Hz/60 Hz	C/E
Taiwan	110 V	60 Hz	A/B
Tajikistan	220 V	50 Hz	C/F
Tanzania	230 V	50 Hz	D/G
Thailand	230 V	50 Hz	A/B/C/O
Togo	220 V	50 Hz	C
Tokelau	230 V	50 Hz	I
Tonga	240 V	50 Hz	I
Trinidad and Tobago	115 V	60 Hz	A/B
Tunisia	230 V	50 Hz	C/E
Turkey	230 V	50 Hz	C/F
Turkmenistan	220 V	50 Hz	C/F
Turks and Caicos Islands	120 V	60 Hz	A/B
Tuvalu	230 V	50 Hz	I
Uganda	240 V	50 Hz	G
Ukraine	230 V	50 Hz	C/F
United Arab Emirates	230 V	50 Hz	G
United Kingdom	230 V	50 Hz	G
United States of America	120 V	60 Hz	A/B
United States Virgin Islands	110 V	60 Hz	A/B
Uruguay	220 V	50 Hz	C/F/L
Uzbekistan	220 V	50 Hz	C/F
Vanuatu	230 V	50 Hz	I
Vatican City	230 V	50 Hz	C/F/L
Venezuela	120 V	60 Hz	A/B
Vietnam	220 V	50 Hz	A/B/C
Virgin Islands (British)	110 V	60 Hz	A/B
Virgin Islands (United States of America)	110 V	60 Hz	A/B
Wales	230 V	50 Hz	G
Yemen	230 V	50 Hz	A/D/G
Zambia	230 V	50 Hz	C/D/G
Zimbabwe	240 V	50 Hz	D/G

Table H-1. Worldwide voltages (continued)

Country/State/Territory	*Single-Phase Voltage*	*Frequency*	*Plug and Outlet Type (see figure H-2)*
Legend: Hz hertz V volt			

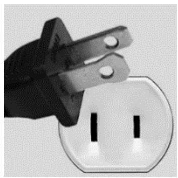
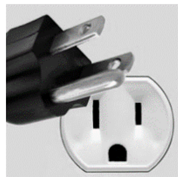
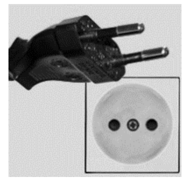
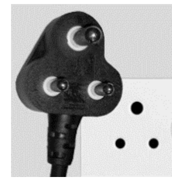
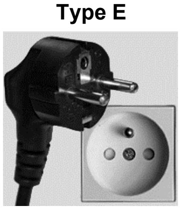
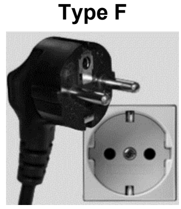
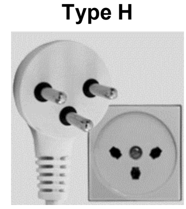
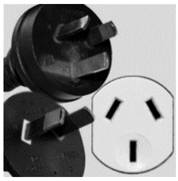
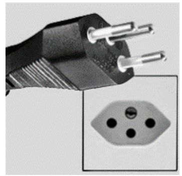
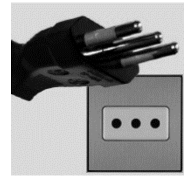
Type A	**Type B**	**Type C**	**Type D**
 Mainly used in the United States, Canada, Mexico, and Japan 2 pins Not grounded 15 amperes Almost always 100–127 volts	 Mainly used in the United States, Canada, Mexico, and Japan 3 pins Grounded 15 amperes Almost always 100–127 volts Socket also compatible with plug type A	 Commonly used in Europe, South America, and Asia 2 pins Not grounded 2.5 amperes Almost always 220–240 volts	 Mainly used in India 3 pins Grounded 5 amperes 220–240 volts Socket also compatible with plug type C Socket unsafe with plug types E and F
Type E	**Type F**	**Type G**	**Type H**
 Primarily used in France, Belgium, Poland, Slovakia, and the Czech Republic 2 pins Grounded 16 amperes 220–240 volts Socket also compatible with plug types C and F	 Used almost everywhere in Europe and Russia, except for the United Kingdom and Ireland 2 pins Grounded 16 amperes 220–240 volts Socket also compatible with plug types C and E	 Mainly used in the United Kingdom, Ireland, Malta, Malaysia, and Singapore 3 pins Grounded 13 amperes 220–240 volts	 Used exclusively in Israel, the West Bank, and the Gaza Strip 3 pins Grounded 16 amperes 220–240 volts Socket also compatible with plug type C Socket unsafe with plug E and F

Figure H-2. Worldwide outlets and plugs

Type I	Type J	Type K	Type L
			
Mainly used in Australia, New Zealand, China, and Argentina 2 or 3 pins 2 pins, not grounded or 3 pins, grounded 10 amperes 220–240 volts	Used almost exclusively in Switzerland, Liechtenstein, and Rwanda 3 pins Grounded 10 amperes 220–240 volts Socket compatible with plug type C	Used almost exclusively in Denmark and Greenland 3 pins Grounded 16 amperes 220–240 volts Socket compatible with plug types C and K Socket unsafe with plug types E and F	Used almost exclusively in Italy and Chile 3 pins Grounded 10 amperes and 16 amperes 220–240 volts 10 A socket compatible with plug types C and L (10 A version) or 16 A socket compatible with plug type L (16 A version)

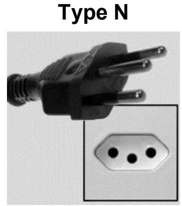
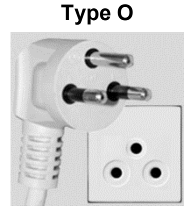
Type M	Type N	Type O
		
Mainly used in South Africa 3 pins Grounded 15 amperes 220–240 volts	Used almost exclusively in Brazil 3 pins Grounded 10 amps and 20 amperes 100–240 volts Socket compatible with plug type C	Used exclusively in Thailand 3 pins Grounded 16 amperes 220–240 volts Socket also compatible with plug type C Socket unsafe with plug types E and F

Figure H-2. Worldwide plugs and outlets (continued)

Glossary

The glossary lists acronyms and terms with Army or joint definitions. Where Army and joint definitions differ, (Army) precedes the definition. Terms for which ATP 3-34.45/MCRP 3-40D.17 is the proponent are marked with an asterisk (*). The Army proponent publication for other terms is listed in parentheses after the definition. Approved Marine Corps acronyms, terms, and definitions can be found in Marine Corps Supplement to the DOD Dictionary of Military and Associated Terms (short title Marine Corps Dictionary).

SECTION I – ACRONYMS AND ABBREVIATIONS

AC	alternating current
ADP	Army doctrine publication
AFCS	Army Facilities Components System
AFH	Air Force Handbook
AR	Army regulation
ATP	Army Techniques Publication
AutoDISE	Automated Distribution Illumination System, Electrical
BEAR	base expeditionary airfield resources
C2	command and control
CJCSI	Chairman of the Joint Cheifs of Staff
COTS	commercial off-the-shelf
DA	Department of the Army
DA PAM	Department of the Army Pamphlet
DC	direct current
DOD	Department of Defense
DSCA	defense support of civil authorities
ESF	emergency support function
FM	field manual
FMF	Fleet Marine Force
GREENS	Ground Renewable Expeditionary Energy Network System
GTA	Graphic Training Aide
HMS	heavy maintenance section
JCMS	Joint Construction Management System
JP	joint publication
kW	kilowatt
MAG	Marine aircraft group
MAGTF	Marine air-ground task force
MCO	Marine Corps order

MCRP	Marine Corps reference publication
MCTP	Marine Corps tactical publication
MEB	Marine expeditionary brigade
MEP	mobile electric power
MEPDIS-R	Mobile Electric Power Distribution–Replacement
MIL-STD	military standard
MOS	military occupational specialty
MST	maintenance support team
MUSE	mobile utilities support equipment
MWSS	Marine wing support squadron
NEC	national electric code
NTTP	Navy tactics, techniques, and procedures
PDISE	Power Distribution Illumination Systems, Electrical
PIN	publication identification number
PPE	personal protective equipment
Prime BEEF	prime base engineer emergency force
PS	preventative services
RED HORSE	rapid engineer deployable heavy operational repair squadron engineer
SASO	Safety and Standards Office
SDC	secondary distribution center
SME	subject matter expert
SPACES	Solar Portable Alternative Communications Energy System
TO&E	table of organization and equipment
TC	Training Circular
TM	Training Manual
UFC	Unified Facilities Criteria
UROC	U.S. Army Corps of Engineers Reachback Operations Center
U.S.	United States
USC	United States Code
USACE	United States Army Corps of Engineers
VAC	volt alternating current
W	watts

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No terms.

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MCRP 3-40D.17

05 February 2024

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