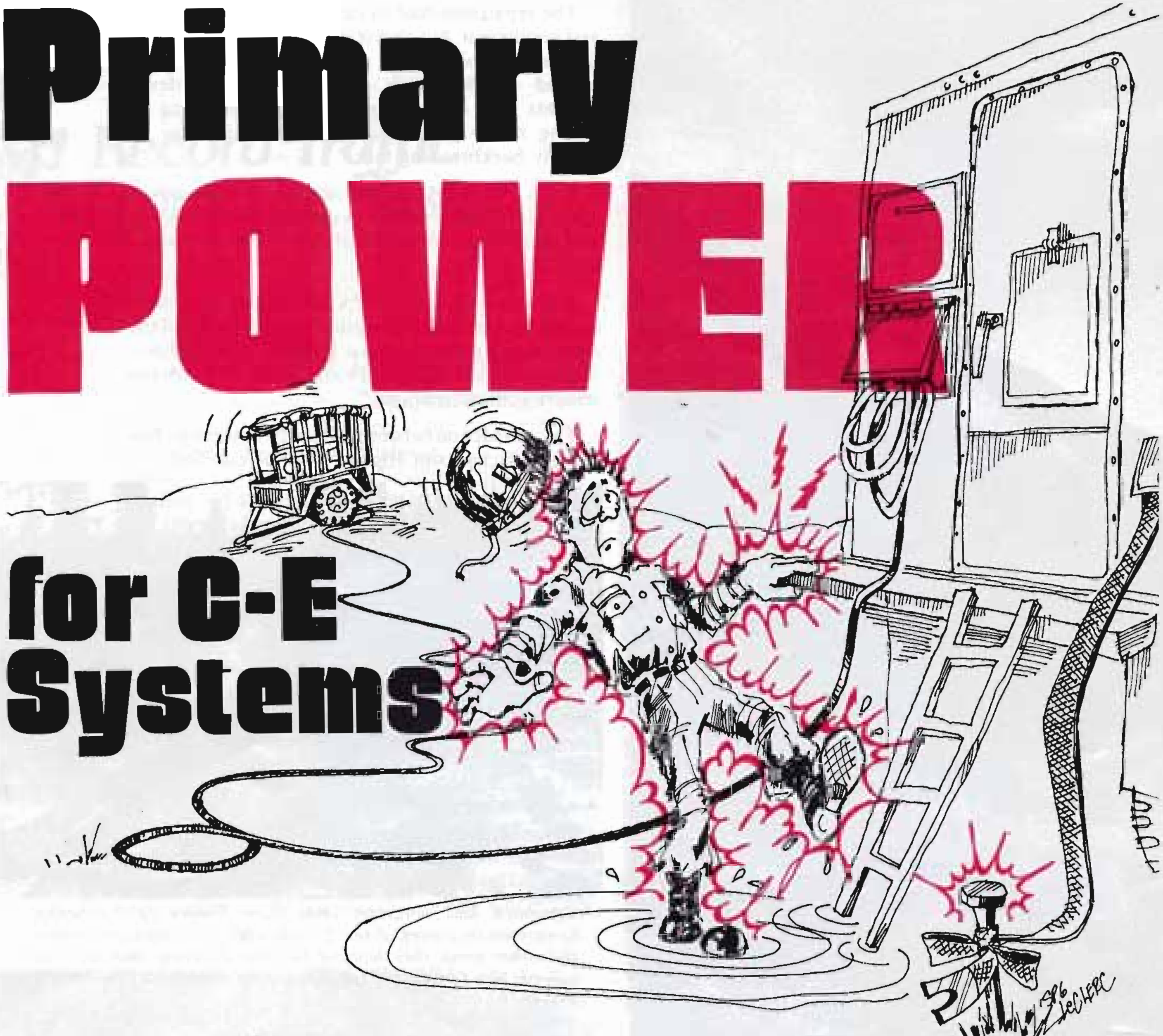
Primary POWER for C-E Systems



Part I

by Kenneth Tollstam, Jr.

One of my last duties before leaving Germany was to observe the operation of several field telecommunications sites involved in Army Training and Evaluation Program (ARTEP) training. One site in particular was operating under the supervision and guidance of 2nd Lt. Nonuttin.

On casual observation, everything looked just fine at this site, designated as RADIO TERMINAL ZULU. The site consisted of several different communications assemblages and was being powered by many different types of tactical generators.

2nd Lt. Nonuttin came up to greet me and Maj. Nowledgeable, the battalion S-4, and to show us around the site. The tour was to begin inside the Operations Center which was an AN/MSC-32. When we approached the MSC-32, Nonuttin cautioned us to jump up on the bottom step of the ladder before touching any part of the truck or van. This way, he said, we would avoid the "tingling" sensation we would get if we touched the truck or van while we were standing on the ground. This was my first indication that there might be a problem at radio site ZULU.

I asked Nonuttin if the MSC-32 was grounded. He said, "Of course it is," and pointed to a length of WD-1 wire trailing down from the POWER ENTRANCE BOX. He did say that they could not find a ground rod for the MSC-32, so they wrapped the WD-1 around a nail and stuck the nail in the ground; but it was a big nail!

When we got inside the MSC-32, I noticed that the lights were very dim. I checked the voltage reading on the POWER INPUT PANEL; it was indicating 90 volts. Nonuttin told me that that was OK because he had 140 volts on another phase of the generator and that balanced things out. About that time all the lights went out.

On the way to the generator to find out what the problem was, I noticed power cables with open splices, ground straps tied in knots to ground rods, people arc welding with signal cables and many people walking around with their hair standing on end. Nonuttin could not determine the problem with the generator; it just would not put out any voltage from the LO terminal. He chalked it up to unreliable, faulty Army equipment.

Finally, Nowledgeable suggested that we move on to the next site. He was getting a bit nervous and very anxious to leave. On the way to the next site, we heard over our radio that Nonuttin was being medically evacuated from the area. It seems that he plugged his electric razor into the convenience outlet on one of the generators, which was grounded to the nearest tree. He was standing in a puddle of water at the time. Ten thousand watts made a believer out of Nonuttin.

Nonuttin fell into a trap common to many communications people. He did not pay enough attention to the primary power needed to operate his communications systems. Ignorance, when applied to a substantial source of primary electrical power, can result in disaster. This article will cover some of the basic concepts required for the safe and efficient handling of primary power for C-E systems.

A prerequisite for stable, reliable telecommunications is stable, reliable primary power. Basically, electricity is the same regardless of the source; however, depending on the source, it can have many different characteristics. Each piece of electronic equipment is designed to operate with a specific characteristic source of primary power, and it is important that the correct characteristic source be used with — and connected correctly to — the piece of electronic equipment involved. This article, therefore, will discuss electrical grounding, the basic power source characteristics, load considerations, the correct procedures for connecting C-E assemblages to the most common military power units (generators), and the correct procedures for connecting C-E assemblages to European commercial power using different types of transformers.

GROUNDING

Grounding your equipment serves three purposes. It protects you and your equipment from being harmed by electricity, especially if something goes wrong inside the equipment. Grounding also provides a measure of protection against lightning, and it makes your equipment work better by eliminating spurious electrical charges.

Let's look at the safety aspects of grounding. A poor safety ground, or one that is wired incorrectly, is more dangerous than no ground at all. The poor ground is dangerous because it does not offer full protection while the user is given a false sense of security. All equipment should be properly grounded before anyone even thinks about applying primary power. Pounding a ground stake at the shelter and generator, if used, and connecting the non-current carrying parts of the equipment — the metal shelter construction and generator frame and trailer — to these ground stakes will not provide full protection. This procedure establishes an earth ground but does nothing for the system ground. One must provide a low impedance ground path back to the "power source neutral" or "system ground" as it is often called. This is accomplished by the use of an "equipment grounding conductor" (EGC). This is the third wire, usually green found in the 120 volt, single phase power cables, as an example. This EGC must be connected with the neutral conductor, the white wire, to the power source neutral which is the system ground, and this in turn must be connected to earth ground. This will insure a grounded power source which is required for C-E assemblages. This also provides a third wire, low impedance safety ground which will provide an electrical path back to system ground in case of a fault in the equipment which could apply source voltage to the metal construction of the equipment. An earth ground alone will not provide a satisfactory path for this type of fault.

Electrical shocks can be very dangerous. The amount of current that may pass through the body, without harm, depends on the individual and the current quantity, type, path, and length of contact time. A current of 1 milliampere (1 one thousandth of an ampere) can be felt and will cause a person to avoid it. Current as low as 5 milliamperes can be dangerous. If the palm of the hand makes contact with a conductor, a current of about 10 milliamperes will tend to cause the hand muscles to contract, freezing the body to the conductor. Such a shock may or may not cause serious damage, depending on the contact time and one's physical condition, particularly the condition of the heart. A current of only 25 milliamperes has been known to be fatal, and 100 milliamperes is likely to be fatal. Aside from being burned to a crisp, people die from electrical shock in two ways. The heart can go into ventricullar fibrillation, which means the heart beats irregularly and has an effect similar to a heart attack. One can also pass out and die of asphyxiation, or in other words, stop breathing. If the shock itself does not cause damage, the involuntary muscle reactions that often result from a shock can also cause physical injury. The need for a properly installed grounding system is clear. An effective grounding system will prevent one's body from accidentally becoming the electrical ground path.

Before one can effectively connect the C-E assemblage to earth ground, he must make sure that all the equipment inside the assemblage is grounded to the internal common grounding system. Some pieces of equipment are grounded via the standard 3 prong electrical plug and receptacles, while others require a separate ground wire, EGC. Making sure the equipment is properly grounded inside the assemblage is just as important as making sure the assemblage is grounded.

Most C-E assemblages have one main ground terminal connector which is usually located in the power entrance box. This is the only connector that should be used to connect the assemblage to earth ground. This connector is attached to the assemblage internal grounding system. Any other grounding terminal found on the assemblage should not be used to connect the assemblage to ground. These other grounding terminals are usually smaller than the ones found in the power entrance boxes, and, in most cases, they are only connected to the frame of the assemblage and not the internal grounding system. These other grounding terminals are found in the signal and video entrance boxes and are for connecting the grounded shielding of certain types of special purpose cables.

GROUND RODS

Now that we know where to make the ground connection on the assemblage, we have to make sure that we have a suitable ground point. The most common grounding device used to provide a grounding point is the ground rod. Ground rods are issued with most C-E assemblages. Issued ground

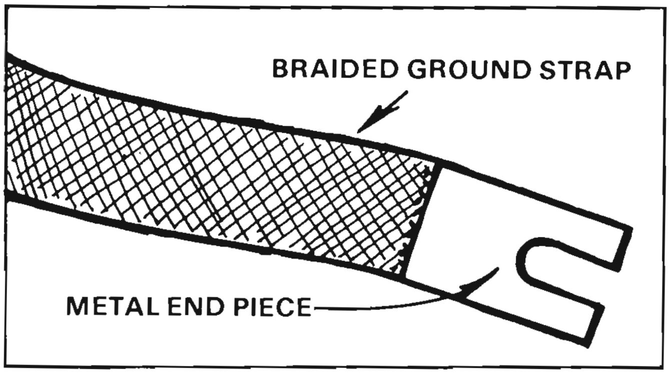


Figure 1. A Typical Braided Metal Ground Strap.

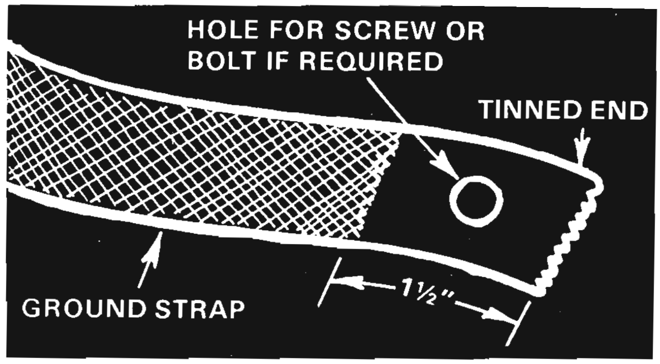


Figure 2. Ground Strap for use with Screw Terminal Device.

rods are made of metal that does not corrode or rust easily. Some rods may be longer and thicker than others, but the ground rod alone will not do the job. A complete ground rod system to include a ground strap (or wire) and a device to connect the strap to the rod (terminal screw or clamp) are both necessary. The best kind of ground strap is made of braided copper material. Issued ground straps are specially treated to retard corrosion. Ground straps should be inspected frequently, however, since they are made of braids of fine wire and fray easily. Also, after a long period of time and exposure to the weather, they will corrode.

Worn or damaged ground straps can be repaired, but the repairs have to be made properly. A ground strap must have both ends prepared for connection to a fastening device. Most ground straps come with metal end pieces clamped and soldered to the ends as illustrated in figure 1.

If a metal end piece is torn off of a ground strap, then that torn end must be repaired. An untreated end of a ground strap does not provide a satisfactory clamping surface for a good, tight connection.

To repair the end of a ground strap requires soldering flux, rosin core solder and a soldering iron rated at least 60 watts. Coat the end of the strap with the soldering flux. With the soldering iron and solder, tin a 1½ inch portion of the end of the strap. This will provide a solid clamping surface for the ground strap. If the ground strap is to be used with a screw terminal device, then a hole must be drilled or punched into the tinned end of the ground strap. See figure 2.

If a ground strap becomes cut or torn in two, it can also be repaired. The important thing to remember is that torn ground straps cannot be repaired by tying the two pieces together in a knot. Simply tying the two together does not provide a tight connection, and corrosion caused by moisture will build up in the knot making the connection worse. The best way to repair a torn ground strap is to prepare each end as illustrated in figure 2, and then bolt and solder the ends together. See figure 3.

The ends may be just soldered together, but the bolt provides the additional mechanical bonding needed to insure that the ends do not separate, even in the event of an electrical fault (short circuit) which may cause the ground strap to heat, thereby softening the solder.

If a ground strap is not available or if there are no facilities or materials to repair a damaged ground strap, or if the ground strap is damaged or corroded beyond repair, the next best thing to use is the heaviest gauge wire available. Eight or six gauge wire is usually sufficient. In any event, the ground strap or wire should be heavy enough to handle the maximum current available from the power source or first current interruption device (fuse or circuit breaker) in the line. The system should be able to survive a lightning blast.

Connecting the ground strap or wire to the ground rod is also important. The ground rod will have either a terminal screw or a clamping device. The ground strap should never be tied with a knot to the ground rod. Fasten the ground strap tightly to the ground rod with either the terminal screw or the clamping devices. The clamping devices, by the way, should be the bolt-on type. Sometimes standard hose clamps and large alligator clips are used; however, these are generally not acceptable because they cannot be tightened sufficiently to make a good connection. If no other clamps are available, hose clamps and hose clamps with soldering are the next best means of attachment.

The three main things to remember about ground straps and wires are: keep them short; make solid, clean connections; and keep the connections clean and tight. Keeping the ground strap or wire as short as possible is important. Generally speaking, if one standard ground strap is not long enough to reach the ground rod or other ground connection, find a closer ground connection. When using wire, make sure it is no longer than one standard length of ground strap (about 10 feet). The longer the ground strap, the more vulnerable it is and the more electrical resistance it introduces into the grounding system. Each assemblage or shelter should have its own ground rod or grounding point, and, if practical, these ground points should be connected with a common bonding conductor. Poor earth grounds are often blamed for "power hum" interference when in reality the problem is usually the potential voltage difference

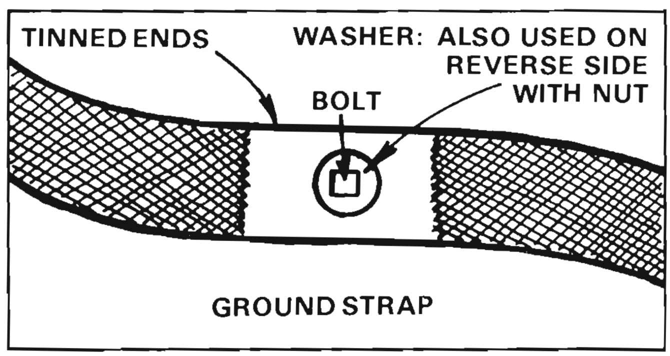


Figure 3. Repair of A Torn Ground Strap.

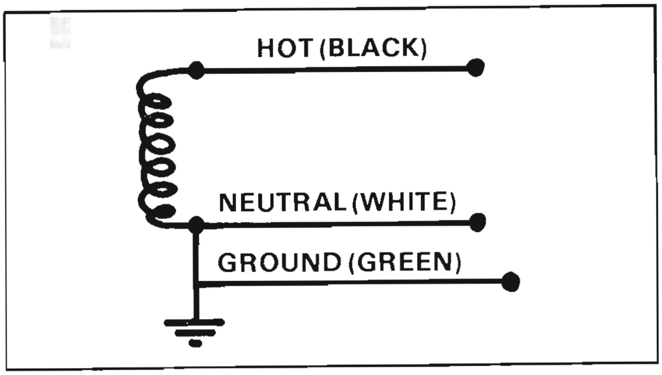


Figure 4. Single Phase 120 Volt, 2 Wire Power Source Configuration.

between earth ground and system ground and the potential voltage difference between associated shelters. Connecting the earth ground to system ground at the power source will help prevent this type of interference. This procedure will be discussed in more detail later on.

How well a ground rod system works depends on the rod and how it is installed. First, clean the rod if necessary to remove any paint, grease or oil. Second, be sure the ground rod is into the subsoil to make a good ground. Topsoil is not a good conductor of electricity. Dig a hole about 6 to 8 inches deep and about 18 inches across. This should get into the subsoil and at the same time provide room to work. Properly driving the ground rod has a direct bearing on how well it will work. Strike the end of the rod just hard enough to drive it into the ground. The lighter the driving blows, the less you disturb the soil and there will be more direct contact between the rod and the soil. Finally, when the end of the rod is about three inches above the bottom of the hole, connect the ground strap or wire to it. Fill the hole with water, let it soak in, then fill the hole with dirt. Keep the soil around the rod moist. A good grounding system should be the result.

For further information on grounding, to include grounding under adverse and unusual situations, see Training Circular TC 11-6, 30 September 1976, *Grounding Techniques*.

BASIC POWER SOURCE CHARACTERISTICS

There are three basic power source configurations (not including the European commercial source) that we deal with most often in the military. All three types can be obtained from most of the common power units (generators) used in the military.

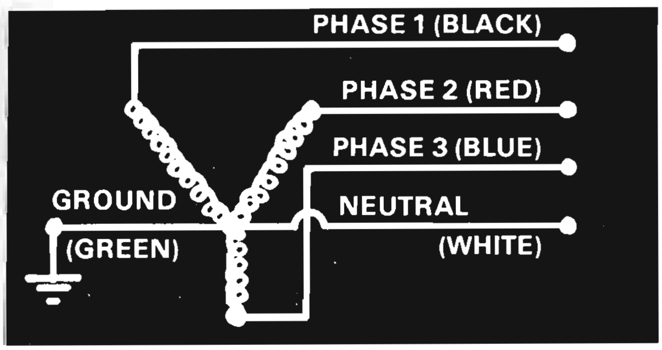


Figure 5. Three Phase 120/208 Volt, 4 Wire Configuration.

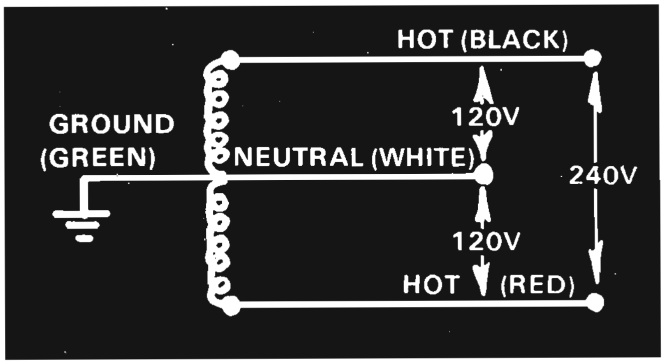


Figure 6. Single Phase 120/240 Volt, 3 Wire Configuration.

The first kind of power is straight single phase 120 volts, 2 wire. This is the kind of power used by the majority of the C-E assemblages. See figure 4.

The second type of power (commonly used in central power distribution systems) is three phase 120/208 volt, 4 wire. See figure 5.

Between any two of the three phases (1 & 2, 1 & 3, 2 & 3) there is a potential of 208 volts. Between any phase and neutral (or ground) — 1 & neutral, 2 & neutral, 3 & neutral — there is a potential of 120 volts.

The last type of power commonly encountered is the single phase 120/240 volt, 3 wire configuration. See figure 6.

All three types described are alternating current (AC) at 60 or 50 cycles per second (Hz). 400 Hz power systems will not be covered here. Where single phase, 3 wire or three phase, 4 wire distribution systems are used, either from utility transformers or from power generators, it is important that each single phase, 3 wire or three phase, 4 wire circuit carry the same amount of load. A 10% tolerance is usually satisfactory. Failure to observe this requirement will result in low voltage on one phase and high voltage on another. The phase windings of an overloaded circuit in the transformer or generator will overheat and possibly damage the equipment. Load banks are available and should be connected to the three phase, 4 wire power distribution systems to precisely adjust the load on each phase by compensating for imbalances.

POWER GENERATOR LOAD CONSIDERATIONS

The power generators most commonly used with communications equipment are the 3 kilowatt (3 Kw), 5 Kw, and 10 Kw. The 15 Kw, 30 Kw, and 60 Kw are usually used in central power distribution systems. All of these generators can provide different kinds of power as selected by an output control switch or by strapping together various control terminals.

The different generators are distinguished by their load handling capacity. The 3 Kw generator can deliver 3,000 watts of power, the 5 Kw can deliver 5,000 watts and so on. It should be noted that when a generator is used in a three phase output configuration, the load capacity is equally divided between the three phases. Thus, a 10 Kw generator in the three phase mode has 3.3 Kw available per phase. When a generator is used in the single phase, 3 wire mode, the load capacity is divided between the two "hot" lines. Thus, a 10 Kw generator would have 5 Kw available from each "hot" line.

In alternating current (AC) power systems, we must concern ourselves with power factors. The power factor is the ratio of true power to apparent power, that is, of watts to volt amperes. The power factor (PF) of the anticipated load must be determined before an accurate estimate of the required power can be made. In direct current (DC) circuits, the power delivered by the generator (in watts) is the product of the current multiplied by the voltage, regardless of the character of the load; no power factor problem is involved. In alternating current (AC) circuits, both the magnitude and the direction of the current and voltage will change at regular intervals. With certain type loads, voltage and current may not rise and fall together. Inductance in an AC circuit causes the current to fall behind the voltage and produce a lagging power factor. Capacitance in an AC circuit causes the current to lead the voltage and produces a leading power factor. Therefore, an unbalanced inductance or capacitance will cause the true power to be less than the apparent power. In a circuit having equal inductive and capacitive reactances, the current and voltage rise and fall in step, giving unity (1) power factor. Where inductive and capacitive reactances are unequal, there is a power factor of less than unity. If there are a number of fractional horsepower inductive motors or partially loaded transformers in a circuit, the inductive element will be increased, and the power factor will be lowered. The load imposed by communications equipment usually results in a power factor between 0.6 and 0.8.

The load rating of a particular generator is determined by the internal heat it can withstand. Since heating is caused mainly by current flow, the generator's rating is identified very closely with its current rating. AC generators are often rated in both kilovoltamperes (KVA) and kilowatts (Kw). The Kw rating of a generator usually assumes a power factor of 80 percent (0.8) or 80 percent of the KVA rating. Where only the KVA rating is given, a power factor of 100 percent (1) is assumed unless otherwise specified. For example, a single phase generator designed to deliver 100 amperes at 120 volts is rated at 12 KVA. This machine would supply a 12 Kw load at unity (1) power factor. With a power factor of 0.8 (80%) it would only supply a 9.6 Kw load. If this generator were to be rated in kilowatts, it would be rated at 9.6 Kw. Conversely, a generator with a rating of 12 Kw would supply a 15 Kw load at unity (1) power factor and a 12 Kw load at 0.8 power factor.

In AC generators, the armature current varies with the load. Lagging power factor loads tend to demagnetize the field, and the output voltage is maintained only by increasing the DC field current. Loads with excessively low power factors would require such a high increase in the DC field current to maintain the proper output voltage that excessive heat would build up in the generator field.

Power factors must be taken into consideration when calculating a load. As stated before, AC generators rated in kilowatts usually have already considered a power factor of 0.8; however, in order to supply power to many different kinds of loads with different power factors, it is important to find the total load expressed in KVA. The KVA capacity of the generator must not be exceeded. Almost all transformers are rated in KVA, and the load considerations for transformers are essentially the same as for generators.

As an example, let's say we must provide power for a communications center that requires 12 Kw of power for incandescent lighting, 18 Kw at 0.8 power factor for general signal equipment and 8 Kw at 0.7 power factor for a large radio transmitter. The power requirements in KVA can be calculated as follows:

(1) Lighting (incand.) and miscellaneous, 12 Kw at unity (1) power factor.

$$\text{KVA} = \frac{\text{Kw}}{\text{PF}} = \frac{12}{1} = 12 \quad \text{KVA}$$

(2) General signal equipment, 18 Kw at 0.8 power factor.

$$\text{KVA} = \frac{\text{Kw}}{\text{PF}} = \frac{18}{0.8} = 22.5 \quad \text{KVA}$$

(3) Radio transmitter, 8 Kw at 0.7 power factor.

$$\text{KVA} = \frac{\text{Kw}}{\text{PF}} = \frac{8}{0.7} = 11.4 \quad \text{KVA}$$

(4) Total connected load = 12 KVA + 22.5 KVA + 11.4 KVA = _45.9 KVA_

(5) Demand load; which is the percentage of connected load which will be operating at the same time. A communications installation is usually rated at 100% demand load. 100% of 45.9 KVA = 45.9 KVA.

(6) Always allow for a reserve of 25 percent.

45.9 KVA + 25% = 57 KVA

The figure, 57 KVA, is the total load figure for the installation and would be used in selecting generators, transformers, service conductors, switches and circuit protection. It is important to arrive at this figure accurately. In this example, a generator rated at 50 Kw to power this installation would have sufficient power. By converting 50 Kw to KVA (50 divided by 0.8) we find that we have 62.5 KVA. Equipment power consumption figures and power factors are usually given on the data plate or in the equipment technical manuals. Where power factors are not given, use 0.8 for general signal equipment and fluorescent lighting and 1.0 for straight resistive loads.

Another factor to take into consideration is the type, gauge, and length of the power cable to be used for connecting the load to the power source. Most communications assemblages and other shelters requiring power are issued with power cables. The issued power cables are usually from 8 AWG (American Wire Gauge) to 4 AWG in gauge and come in 100 foot lengths with 15 foot stubs for connection to load terminals. The current handling capacities of the cables run from 40 to 90 amperes, depending on the gauge and type of insulation. A good rule of thumb to follow with standard military power cables and cable assemblies is not to exceed 60 amperes. Standard military power cables should not be extended longer than 200 feet between the source and the load. The cable resistive losses beyond 200 feet may cause the voltage to drop below acceptable limits at the load end of the cable, especially under high current demand situations. You may not always be able to compensate for this loss in voltage by increasing the output at the source as this may deliver higher than acceptable voltage to equipment connected closer to the source. Another general rule is to never connect more than two shelters together POWER OUT to POWER IN. See figure 7.

Figure 7. Two-Shelter POWER OUT To POWER IN Configuration.

The third shelter should be connected directly to the power source. This rule will prevent excessive current flow through the cable between the power source and the first shelter. It also prevents a drop in voltage from appearing at the third and consecutive shelters connected in the chain.

The standard military power cables issued with the shelter assemblages are suitable for temporary underground installation. If more than one cable is to be used, the cable "hock" connection should not be placed underground unless it is properly waterproofed. Because of the lack of adequate waterproofing materials in the field, it is better to leave the power cable "hock"connection above ground. The cable "hock" connection should be made in a location where it will be protected from vehicle traffic and any other hazards. It is also a good idea to provide as much protection as possible for the power "hock"by covering it with canvas or wood or some other suitable material.

Power cables should never be laid parallel with signal cables. Inductance from the power cable into the signal cable will result, especially if the power cable is handling a high current load. This will adversely affect the communications circuits and is the most common source of "Power Hum" noise.

Power cables can be repaired at the organizational level. The extent of repair should be limited to the replacement of the power "hock" connector. Power cables should never be spliced except in emergency situations. When replacing power cable "hock" connectors, strict attention should be paid to the organizational repair manual. It is very important to connect the proper cable conductor to the proper cable connector terminal. The standard, single phase, "flat", 3-conductor power cable (CX-7453(*)/U 100 foot and CX-7705(*)/U 15 foot stub) is the most common power cable in use. The three conductors in the cable are color coded. One conductor is always black, another is always white, and the last, which is usually a lighter gauge than the others, is green. The black conductor is always the "hot" line, the white conductor is always the neutral return line, and the green conductor is always the ground line. This power cable has a connector (U-237/G) on each end (or on one end in the case of the 15 foot power stub). The number one pin is always connected to the "hot", black conductor, the number two pin is always connected to the neutral return, white conductor, and the G4 pin is always connected to the ground, green conductor. See figure 8.

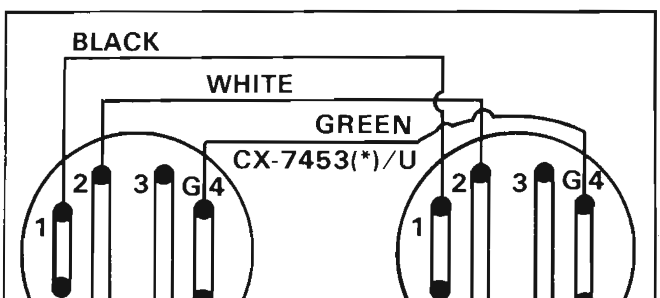


Figure 8. Schematic Diagram of 3-Conductor Power Cable CX-7453(*)/U and Connectors U-237/G.

There are other types of power cables used with different types of shelters. Always consult the appropriate technical manual before attempting repair on a power cable assembly. An improperly wired power cable assembly could cause damage by applying high voltage to equipment in the case of multi-phase or single phase, 3 wire, power requirements. An improperly wired power cable could also result in source voltage being applied directly to the metal construction of the shelter. This is commonly known as a "hot" shelter. This situation can be very dangerous. This is another reason why it is important to connect the earth ground to system ground via the equipment grounding conductor, EGC, at the power source. If there is a "hot" shelter situation, an earth ground alone will not have sufficient conductance to disengage the circuit breaker or fuse at the power source. If the ground is connected to system ground (power source neutral), this will create a low resistive, direct electrical "short circuit" back to the power source in the event of a "hot" shelter, thus activating the circuit protection devices. The method of connecting earth ground to system ground (power source neutral), at the power source, will be illustrated later.

Finding a "hot"shelter is a matter of elimination (though finding out that a shelter is "hot" in the first place may not be a pleasant experience). If the offending shelter is connected to a common earth ground with other shelters, all the shelters will be "hot". Each suspected shelter should be isolated from the others by disconnecting all common grounds and signal cables. Also, if the suspected shelter is getting power from another shelter, either of the two shelters could be the cause of the problem. Once the suspected shelter and associated power cable are totally isolated, replace the power cable. If replacement of the power cable corrects the problem, the original power cable is defective and should be repaired or permanently replaced. If replacement of the power cable does not correct the problem, the problem is probably with the shelter itself. In this case, higher maintenance (Direct Support) should be called in to correct the problem.

In Part Two of 'Primary Power for C-E Systems,' which will appear in the next issue of TAC, Tollstam deals with common power generator connections. In addition, he discusses step-down power transformers, which are often necessary in Europe where standard commercial power is three phase, 220/380 volt, four wire.

Kenneth Tollstam, Jr. has served four years in tactical Signal battalions in Europe. He has also served as the OIC of an electronics maintenance shop and as a C-E commodity manager for the 9th Infantry Division where he was promoted to WO2. Tollstam holds a B.A. from St. Martin's College in Washington. He recently separated from the Army.