AUXILIARY POWER

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Introduction

Amateurs can't learn all that they need to know about auxiliary power for emergency communications just from books or lectures. Practical experience is needed to apply the theory with common sense. The following won't make you an expert, but provides enough basic knowledge to "keep you out of trouble," explain the basics of battery- based DC power systems, portable generators and photovoltaic to enable you to plan adequate auxiliary power for emergency communications equipment. Always remember that batteries are only a temporary power source unless you have a sustainable recharging means, not dependent upon the AC mains. Photovoltaic (PV) systems can provide that sustainable DC power at lower life-cycle cost than generators, when combined with a properly designed battery bank and charge controller.

Attention to POLARITY is always important, but is especially so in DC systems! Whenever using battery power, the correct connection sequence is important to avoid sparking or damage to system components. Just because the battery is lower than your house current does not mean it is harmless. An arc caused by wiring a connection in the wrong order may ignite hydrogen given off by a battery, causing an explosion! High current flows at low voltages can still be lethal. Always disconnect all circuits before working on any power system and always follow the correct reconnection sequence:

- positive connection to battery
- positive connection to load
- negative connection to battery
- negative connection to load

Batteries

Typical 12-volt lead-acid batteries have a voltage of about 14 volts when fully charged and 11 volts fully discharged. Because most communication equipment doesn't operate properly below about 11.5 volts, you can't exceed the depth of discharge which depletes the battery voltage under load to below that figure. Battery systems are current limited and their capacity is finite. Oversized loads or excessive duty cycle cause rapid depletion of battery capacity, so battery systems must be sized to match the load, or else they cannot supply the current needed.

You must pay attention to how battery performance ratings are measured. Cold Cranking Amps (CCA) used to rate starting batteries represent the current a battery can provide continuously for 30 seconds at 0 degs. F before cell voltage is depleted to 1.7V per cell, at which point it is fully discharged. For MCA or Marine Cranking Amps, the measurement is taken at 32 degs. F. Cranking amps tell nothing about how long a battery can run a transmitter. Reserve capacity is the length of time a starting battery can sustain a continuous 25 amp load before cell voltage is depleted to 1.7 volts per cell.

The performance measurements used for rating deep cycle batteries are amp-hour capacity and depth of discharge (DoD). Amp-hour capacity is total current available over time, measured at 80 degs. F. DoD is the percentage of battery capacity available during a charge- discharge cycle. Amp-hour ratings of deep cycle batteries are usually based upon a discharge rate at 1/20 of the battery's capacity, expressed as "C over 20". A marine battery rated 200ah at C20, discharged continuously at 10 amps, at 80o F., sustains that load for 20 hrs. "Starting" batteries are designed for 20% DoD, gel cells 25%, "deep cycle" batteries 50% to 80% and flooded NiCads 100%.

Starting batteries perform poorly for communications because they are designed for short periods of high load. Deep cycle batteries are acceptable and flooded NiCads best for communications because they withstand long periods of slow discharge. In a typical 25% transmit duty cycle, a 100w VHF repeater, drawing 20 amps on transmit, requires a minimum 100ah battery to stay within a C20 discharge rate, at 80o. F. At lower temperatures available capacity is reduced. Lead-acids lose 50% of their capacity at 32oF! More rapid rates of discharge, such as using a marginally sized battery for the load, further reduce available capacity and the number of charge- discharge cycles the battery will provide. A 25 lb., 31 ah wheelchair gel cell is well balanced to power a 2-meter mobile at 25% duty cycle, on medium power transmit, requiring 6 amps for 25w PEP, approximating C20 rate of discharge. If transmit power is increased to 50 watts, current draw is increased to 10 amps. This mildly oversized load approximates C10, and will significantly shorten the life cycle life of a gel cell! A deep-cycle, flooded lead-acid tolerates C10, with some loss of life cycle. A portable battery pack designed for C10 discharge ideally would use NiCad or AGM construction.

A rule of thumb which approximates C20 discharge is one amp-hour per PEP watt. This is adequate for 24 hours of typical CW or SSB duty cycle, or 12 hours of FM or digital. Estimate the amp-hour capacity required to run your station for 24 hours by summing all loads: transmit current times total operating time times duty cycle, plus receive current with squelch open times standby time and repeat for each piece of equipment. Then multiply the total loads by a 150% safety factor. If you are too lazy to actually run the numbers, use the "1 amp-hour per PEP watt" rule for each 24 hours of CW or SSB operation or 12 hours of FM or digital to ensure an adequate safety margin.

Lead-acid batteries are most common and consist of lead alloy grid plates coated with lead oxide paste which are immersed in a solution of sulfuric acid. In manufacture the plates are subjected to a "forming" charge which causes the paste on the positive grid plates to convert to lead dioxide.

The paste on the negative plates converts to "sponge" lead. Both materials are highly porous, allowing electrolyte to freely penetrate the plates. Plates are alternated in the battery, with porous, nonconductive separators between them, or with each positive plate surrounded by an envelope, open at the top. A group of negative and positive plates with their separators makes up an element. When immersed in electrolyte, an element comprises a battery "cell." In lead acid batteries each cell is nominally 2 volts. Multiple cells are connected in series to increase voltage.

Larger or more plates increase amp- hour capacity, but not voltage. Thicker or fewer plates per cell allow more cycles and longer life for the battery. The lower the antimony content in the plates, the lower the internal resistance and the less resistant the battery is to charging. Less antimony also reduces water consumption through electrolysis. However, pure lead has low strength and may break during transportation or service operations requiring removal of the battery. More antimony allows deeper discharge without damage to the plates and longer service life. The plates in most automotive batteries are 2-3% antimony and deep cycle batteries 5-6% Sb. Calcium or strontium are used in sealed lead-acid batteries, and offer the same benefits and drawbacks as antimony, but reduce self discharge when the battery is stored without being used. Do not exceed 25% DoD with Pb-Ca batteries.

Cells in lead-acid batteries are vented to permit hydrogen and oxygen to escape during charging and to provide an opening for replacing water lost due to electrolysis. Open caps are common in flooded batteries, but some caps are of flame arrester type to prevent a flame outside the battery from entering the cell. "Recombinant" caps contain a catalyst which causes hydrogen and oxygen liberated during charging to recombine into water, reducing the need to replace water lost from the battery. These are highly recommended for stationary batteries in seasonal equipment left for extended periods on maintenance level float chargers or used in photovoltaic systems.

The percentage of acid in battery electrolyte is measured by its specific gravity (Sg). Only batteries which use acid electrolyte can use specific gravity as a measurement of the state of charge. A hydrometer is used to measure how much the electrolyte weighs compared to an equal quantity of water. The greater the state of charge, the higher the specific gravity of the electrolyte. The lower the state of charge, the weaker the acid and the lighter the electrolyte. Differences in acid density are measured by the float in a hydrometer, which rises higher in an electrolyte sample of high Sg than in one with a lower Sg.

Measuring Sg of a wet, lead-acid battery during discharge is a good indicator of the state of charge. A fully charged battery has an Sg of 1.265 grams per cubic centimeter, at 75% charge 1.225, 50% charge 1.19 and fully discharged 1.120. During charging of a flooded battery Sg lags the charge state because complete mixing of the electrolyte does not occur until gassing commences near the end of the charge cycle. Because of the uncertainty of mixing, this measurement on a fully charged battery is a better indicator of the health of a cell. Therefore, Sg is not the absolute measure of capacity, but is considered in combination with load testing and open circuit voltage. Lead-acid batteries normally accept only about 1/10 of the charging current at 30 degs. F which they will accept at 80 degs. F. Correct charging current for lead-acid batteries at normal ambient temperature is between 1/10 and 1/20 of battery capacity.

When not in service, all lead-acid batteries self- discharge at rate of about 5% per month. The rate of self discharge increases with the temperature. If a lead-acid battery is left in a deeply discharged condition for a long time it becomes "sulfated" as sulfur in the acid combines with lead from the plates to form lead sulfate. Auxiliary batteries should be connected to a charge controller to provide a regulated, low-level current to compensate for self discharge and protect against sulfation. They also require regular test and inspection, including replacement of lost electrolyte. If water is lost during charging and not replaced, the process of sulfation is accelerated in those plates which are partially exposed to air. "Treeing" is a short circuit occurring between positive and negative plates. This may be caused by manufacturing defect or rough handling resulting in misalignment of the plates and separators. "Mossing" caused by circulating electrolyte bringing particulate matter to the tops of the plates can also cause a short.

Sealed, flooded (wet) lead-acid batteries are sometimes called "maintenance free" and experience less self-discharge. They contain lead-calcium or lead-strontium plates to reduce water loss and usually have catalytic recombiners to reduce water loss and sealed, valve regulated vents. Sealed-flooded lead-acids can tolerate the same temperatures as unsealed batteries, but because Sg cannot be readily measured, some sealed-wet batteries are provided with a captive float hydrometer in the electrolyte. Sealed-wet batteries are common for automotive starting, but should not be discharged below 25%, or their life is dramatically shortened. If you power your transceiver directly from the car battery, take care to run the engine for ten minutes out of every hour to keep the battery charged.

Sealed lead-acid (SLA) batteries with stabilized or "starved" electrolyte include gel cells and absorbed glass mat (AGM) types, which are valve-regulated and completely sealed. Since there is no free liquid electrolyte to spill, the battery can be used safely in any position. SLAs are much safer than flooded types for indoor use and in sensitive equipment such as uninterruptible power supplies for computers, which would be damaged by acid spills or exposure to acid fumes. Any sealed battery will vent if overcharged to the point of excessive gassing, because the valves are designed to purge extreme pressure building up inside the battery case. Self discharge of gel cells is minimized by storing them in moderately cool areas of 5 to 15 degs. C.

Gel cells are **NOT** deep cycle. A DoD of greater than 25% significantly reduces their life. They must never be used below -20 degs. C, in the engine compartment of vehicles or in uses subjecting them to temperatures above 50 degs. C.

Absorbed glass matt (AGM) batteries are deep cycle, can be quickly recharged with no current limit and provide a broad operating temperature range. Their extreme depth of discharge equals flooded NiCads, but with virtually no maintenance and low life cycle cost. New aviation AGMs are substantially more expensive than flooded deep cycle batteries of equal capacity, but are much less expensive than flooded NiCads. Marine or emergency vehicle AGMs such as Lifeline or Optima are not prohibitively expensive, have aviation type cell construction and are recommended as auxiliary power for emergency communications systems.

Flooded nickel cadmium (NiCad) batteries have a physical structure resembling lead-acid batteries, but use nickel hydroxide for the positive plates, cadmium oxide for the negative plates and a potassium hydroxide electrolyte. Therefore, flooded NiCads are not subject to sulfation. Cell voltage of a typical NiCad is 1.2 volt, rather than 2 volts per cell as for a lead-acid. Flooded NiCads can survive freezing and thawing without any affect on performance and are less affected by high temperatures. The self-discharge rate of flooded NiCads ranges from Flooded NiCads can be totally discharged without damage and their ability to accept charging is less affected by the ambient temperature than for lead-acids. Their lower maintenance cost and longer life cycle makes them a logical choice for repeater back-up systems in remote or dangerous locations. However, flooded NiCads cannot be tested as accurately as a "wet" lead-acid battery, because specific gravity of their electrolyte does not change with different charge states. If constant charge monitoring is a requirement, flooded NiCads are not the best choice.

Dry NiCads used in portable transceivers require care to avoid deep discharge, which causes cell reversal or overcharging, which results in irreversible heat damage. Most amateurs are overly concerned about their dry NiCads developing "memory" from being left charged for a long time. Most dry NiCads do not fail from "memory," but from overcharging. Always bring a discharged dry NiCad pack back at a slow controlled rate, but don't charge more than 14 hours. A cell which has developed memory or which has been overcharged can usually be restored by one deep discharge/recharge cycle as long as it doesn't out-gas. A weak battery must never be used without recharging, as irreversible damage occurs inside a discharged dry NiCad when a load is applied to it.

Wire and Connectors

The use of properly sized wire and appropriate connections is important in DC power systems. DC polarity must be maintained throughout the system, as must color coding conventions of wire insulation: positive-red, negative-black and equipment ground-green or bare, following the DC wire color conventions used in automobiles. Additional NEC requirements apply to large DC power wiring systems. Wire gages are much larger than in typical AC systems, because undersized wiring causes excessive voltage drops which result in loss of available power, which causes some loads to work poorly, or not at all. For instance, if too small a wire gage is used between a charge controller and battery, the voltage drop measured during full charging rates reduces the set-point the battery is re- charged to, reducing its operating capacity and life cycle.

To minimize the effects of voltage drop, keep cable runs as short as possible. For instance, in a 12-volt system with a 10 amp load, such as a 2-meter mobile transceiver, the AWG #14 wire normally provided results in a 5% voltage drop over 11 ft. AWG #

Batteries are connected in series to increase voltage or in parallel to increase their amp-hour capacity. These interconnected groups of batteries are called "battery banks." To determine the size of the battery bank needed, determine the daily power requirement in watt-hours times the number of days the equipment must operate the loads without recharging, plus a 30% safety factor to ensure the batteries are not damaged from excessive discharge. To convert watt-hours to amp-hours, divide by the voltage.

Even when partially charged, an interconnected battery bank can deliver sufficient voltage and current to arc weld! Always be careful around battery banks. Keep sparks and other ignition sources away at all times. Never allow tools to fall onto terminals or connections. Never permit construction or use of shelves above the batteries. Battery banks must always be adequately vented.

When paralleling batteries, reduce the effects of voltage drops which cause unequal resistance’s between parallel branches, so that all batteries in the system operate at an equal current and voltage level. This is done by using the same length of cable from each battery terminal to a central junction point. Positive and negative do not necessarily have to be of the same length. This eliminates uneven voltage drop between batteries. Battery cable size is calculated based upon the peak charging and load current demands of the system multiplied by the resistance of the wire. Marine grade or multi strand welding cable of AWG #8 or larger is recommended.

Trouble Shooting Battery Problems

Most battery problems are caused by oversized loads or equipment operating at excessive duty cycle for too long. When batteries are in a low state of charge, it is necessary to check the load as well as the batteries and charging system! The four ways to determine the charge state of lead-acid batteries, in declining order of accuracy are:

- hydrometer/refractometer
- actual equipment load test
- artificial load test
- open circuit voltage

When using a hydrometer you are working with strong acid. Wear eye and face protection and rubber gloves. Have baking soda and plenty of fresh water ready to neutralize spills. To use a hydrometer, squeeze the bulb while the inlet tube is still above the electrolyte level. Then lower the hydrometer into the electrolyte and slowly release the bulb to draw in the electrolyte. At the first cell being checked, fill and drain the hydrometer three times before removing a sample. This brings the hydrometer to the same temperature as the electrolyte. Take a sample and allow the bulb to fully expand. The sample must be large enough to completely support the float.

Hold the hydrometer straight up and down, so that the float does not touch the sides, top or bottom of the tube. Look straight across the electrolyte level to read the float. Ignore the curve of the electrolyte on the sides of the hydrometer. Be careful not to drop the hydrometer or allow acid to drip out of it. After reading the hydrometer, to empty it slowly squeeze the bulb again with the inlet inside the cell, but just above the electrolyte level to reduce risk of spills. Record the Sg of each cell on a work sheet. After use, rinse the hydrometer with fresh water at least five times to flush out any acid. Allow it to dry completely before using it again.

Temperature compensation is required for batteries not at 80 degs. F. Use an accurate glass thermometer and immerse only the thermometer bulb into the acid, leave it for 5 minutes, read it and then rinse in clear water. For every 10 degs. F above 80 degs. F a factor of 0.004 must be added. Subtract the same factor for each 10 degs. below 80 degs. F. As an example, if a battery at 30 degs. F has an Sg of 1.240, the battery is 50 degs. below the standard, so the compensation is subtracted from the specific gravity. The compensation to be subtracted is .004 x 5 =3D .020; so 1.24 - .020 =3D 1.220. A refractometer is the most accurate way to measure electrolyte Sg, requires only a small amount of fluid and is automatically temperature corrected. Refractometers are compact, rugged and recommended for ongoing maintenance of large auxiliary power systems.

To test the no-load, open circuit voltage an accurate DC voltmeter is required. Operate the loads from the batteries for five minutes to remove any surface charge the battery plates may have. Turn off the loads and disconnect the batteries from the rest of the system. Now measure the voltage across the terminals of every battery. Open circuit voltage without a load is a good preliminary indicator of the state of charge. The open circuit voltage of a fully charged 12-volt battery is over 12.72 volts, whereas it is about 12.6 at 75%, 12.48 at 50%, and 12.12 at 25%.

To perform a load test, after recording no-load voltage, reconnect the system, but leaving float chargers, charge controllers or solar arrays disconnected. Operate the equipment at its normal duty cycle for an hour, disconnect the batteries and measure the battery voltages again. If any battery indicates a voltage of 10 percent higher or lower than others, it should be serviced or replaced. An automotive load tester can be used, although you must be aware that this places a large artificial load on the batteries for a short time rather than waiting for a small load to slowly discharge the batteries. Because available capacity is reduced at faster rates of discharge, this test is not as reliable for communication use as a load test done at the normal system duty cycle and rate of discharge.

Accurate trouble shooting requires that all batteries in a bank and individual cells of unsealed, wet-type batteries be numbered. Recording a system history identifies patterns and trends and is a great time saver for others who may service your system in an emergency, because they can focus first on the most frequent problems and can anticipate the proper tools and materials to bring. Battery systems which are not used on a regular basis must be checked in the spring and fall, at minimum. Monthly is recommended.

First disconnect all loads. If battery tops are wet or dirty, remember that fluid on top of the battery is highly acid electrolyte! Clean battery tops with a cloth or brush and a baking soda and water solution. Rinse with clean water and dry with a clean cloth. Remove the caps from all cells, check the electrolyte level of every cell in every battery and add distilled water to the fill line on the battery, or =BD" above the top of the plates. Determine the battery's state of charge with a hydrometer. Discolored, odorous electrolyte indicates contamination caused by adding other than distilled water, which results in battery failure. Inadequate charging without adding water can result in lead sulfate shorts between the plates, cracked partitions between cells and leakage which require the battery to be replaced.

NEVER hammer cable connections onto terminal posts !!! This breaks fragile spot welds between terminal posts and plates, causing shorts, which could cause a spark and ignite free hydrogen gas, causing an explosion! Inspect all caps for sound good condition, replace and tighten securely by hand only. Tighten battery tie-downs securely, but not so tight as to distort the case. Batteries that will not accept a charge may be rejuvenated for a short time by adding a conditioner available from marine and auto stores, but this is only an emergency measure until they can be replaced. Such batteries have had their electrolyte boiled off from prolonged overcharging, or become sulfated by being left at a low state of charge for too long or have suffered physical damage and should be replaced.

Inspect and repair any corroded, loose or burnt connections and blown fuses. Cartridge fuses don't look different when they are blown, so remove them and check continuity with an ohmmeter. A blown fuse shows an infinite reading, a zero reading means it is still intact. Always determine why a fuse blew before replacing it. Proceed logically and check the most obvious things. Check for excessive voltage drop at the load. Knowing what failed is necessary to avoid repeating the condition that caused the failure. If the same fuse blows again, don't consider the system operational again until everything has been checked out.

Portable Generator Basics And Safety

If you can't recharge your batteries when the "grid" is "down" after a disaster, they are useless. Generators frequently come to mind, but are not the only answer. If you don't know what you are doing, stay away from generators, because a screw up may kill you!

NEVER connect a portable generator to the house wiring unless a transfer switch has been hard-wired into the breaker panel to disconnect the house wiring from the AC mains to prevent back-feed when they come back up. Installing one is a job for a licensed electrician. Ensure adequate earth ground for your personal safety. Never run a generator in standing water or work on the generator or feed lines while standing on wet ground. Never run a generator inside an enclosed building because it is impossible to adequately ventilate carbon monoxide and fumes. Use only UL-listed 3-wire extension cords. Always plug cords into equipment first before connecting them to the generator feed. Medical devices and computers require "clean" power and should never be run directly from unconditioned generator feeds.

Gasoline generators produce about 600w at 120 volts AC for each engine horsepower. A typical HF transceiver requires about 1200 AC watts at 120 volts. Generator capacity must be sized to not only the running wattage’s of the equipment, but also the starting loads. For low-load motors such as furnace fans multiply running wattage’s x 2, for heavy loads such as pumps or compressors multiply the running wattage’s x 7. A 3.5 HP generator is about the minimum recommended for VARACES use. It can be carried by one person, uses 5 gallons of gas every 24 hours and produces about 2 kW. It can power a modest station, such as a "barefoot" 100w-SSB or dual-band FM mobile, laptop, TNC, a couple HT dry NiCad battery chargers, 10 amp automotive battery charger and limited emergency lighting. Don't expect it to also power your 180-watt VHF amp, refrigerator, hot plate and coffee pot. Light-duty recreational generators are not rated for continuous duty, may quit and not restart under disaster conditions. The best use for a portable generator is intermittent use to power battery chargers, essential emergency lighting, some cooking and limited use of minimum essential power tools.

The minimum generator to power an average house or an emergency command post is 4.5 to 5 kW. A commercial grade, continuous-duty generator of this size has an 8 HP engine, weighs 200 lbs., produces 32A at 120 volts and runs 8 to 10 hours on 5 gallons of gas and uses a 55-gal drum of gas every three days. A large generator is practical only if you have a reliable fuel source. It is unsafe to store more than one Jerry can of gasoline in your garden shed. Stored gasoline goes bad in a few months unless treated with a stabilizer. Store extra Jerry cans empty. When a severe weather "Watch" changes to a "Warning," fill your extra cans while there is still power to run the pumps, then store them under cover, but outside! Once the generator is started, use a wooden dipstick to check the fuel level every 2 hours and "top off" tanks before they run out.

Photovoltaic Make Sense

Photovoltaic's produce DC electricity from sunlight and are ideal for maintaining battery banks against self-discharge during extended periods of nonuse. Properly designed solar arrays can also provide sufficient current to run communications equipment directly or to maintain battery banks at operating capacity during periods of heavy load. A photovoltaic panel producing a current of 1/100 of the battery capacity is recommended to compensate for self- discharge in storage batteries and can maintain them on "float" indefinitely. No charge controller is required because maximum current doesn't reach the threshold to evaporate electrolyte after full charge is reached. A diode is wired in series with the panel to prevent battery discharge at night when panel voltage drops below battery voltage. This method of float charging is recommended for storing vehicles or equipment which are not used at least monthly.

Additional panels may be added to the system to replace energy consumed daily by the loads and to compensate for energy used by charge controllers, etc. To avoid over- charging the batteries during periods of nonuse, a charge controller is required to disconnect the panels from the batteries when they reach a fully charged state. While voltage is nearly constant, the charging current produced is dependent upon the incident light in watts per square meter under operating conditions. Under ideal conditions, full sun perpendicular to the panel in clear sky at 20 degs. C this figure is about 800w/m2.. A 50 watt panel may produce 1,500+watt/hours of energy weekly under full sun or even more ideal laboratory conditions, but realistically only a fourth as much during a cloudy mid-Atlantic winter.

Therefore, to properly size a photovoltaic system adequate to operate continuously, total all loads in watts, multiply by the average daily use in hours, plus a 30% allowance for DC line losses. Subtract the average daily energy produced by back-up generators and divide the total by the product of the module power rating times the "Area Factor" which compensates for local sun conditions ("4" in the mid- Atlantic states) to yield the number of panels required.

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