5 Power sources and batteries

5.1 Power safety

As in antenna work, for safety purposes any electrical work should be done with a second person present. A switch should never be used in the neutral wire without also disconnect the equipment from an active or “hot” line.

All communications equipment should be reliably connected to an Earth ground by means of a separate heavy gauge wire. The power wiring neutral conductor should not be used for this safety ground. This places the chassis of the equipment at Earth ground potential for minimal RF energy on the chassis. It provides a measure of safety for the operator in the event of accidental short or leakage of one side of the power line to the classis.

No battery should be subjected to unnecessary heat, vibration or physical shock. The battery should be kept clean. Frequent inspection of leaks is recommended. Electrolyte that has leaked or sprayed from the battery should be cleaned from all surfaces. The electrolyte is chemically active and electrically conductive, and may ruin electrical equipment. Acid may be neutralized with sodium bicarbonate (baking soda), and alkalis may be neutralized with a weak acid such as vinegar. Both neutralizers will dissolve in water, and should be quickly washed off. The neutralizer should not be allowed to enter the battery. Gas escaping from storage batteries may be explosive. Keep flames or lighted tobacco products away.

When working with generators, keep safety foremost in your mind. Gasoline is a dangerous chemical and there is no scope for carelessness. Fuel should be stored only in the proper containers, well away from the generator and out of the sun. The generator should be turned off and cool before adding new fuel. Gasoline and oil-soaked rags should be disposed of properly. If they are tossed in a pile, they could catch fire by spontaneous combustion. A fire extinguisher should be kept near the generator. Smoking should not be allowed near the generator.

Internal combustion engines produce heat. The larger the engine, the higher the speed, the greater the heat produced. The combination of fuel fumes and engine heat in a small enclosure is dangerous. Generator exhaust fumes can be lethal. Whether gasoline, diesel, natural gas or propane is used, be sure that exhaust fumes are properly vented out of the operating area. Natural ventilation is usually not sufficient to maintain a safe atmosphere. A blower or ventilator fan should be used to bring fresh air from outside, with an exhaust fan installed to expel the heat.

5.2 Mains power

Mains power should be used when available to save any self-generated power systems for backup purposes. Even unreliable mains power can be used to charge batteries.

Electrical service enters buildings in the form of two or more wires to provide 100-130 V or 200-260 V alternating current at 50 or 60 Hz. The circuits may be divided into several branches and protected by circuit breakers or fuses.

A ground fault circuit interrupter (GFCI or GFI) is also desirable to safety reasons, and should be a part of the electrical power wiring if possible.

5.3 Power transformers

Numerous factors should be considered in selecting transformers, such as input and output volt-ampere (VA) ratings, ambient temperature, duty cycle and mechanical design.

In alternating-current equipment, the term “volt-ampere” is often used rather that the term “watt”. This is because ac components must handle reactive power as well as real power. The number of volt-amperes delivered by a transformer depends not only upon the dc load requirements, but also upon the type of dc output filter used (capacitor or choke input), and the type of rectifier used (full-wave centre tap or full-wave bridge). With a capacitive-input filter, the heating effect in the secondary is higher because of the high peak-to-average current ration. The volt-amperes handled by the transformer may be several times the power delivered to the load. The primary winding volt-amperes will be somewhat higher because of transformer losses.

A transformer operates by producing a magnetic field in its core and windings. The intensity of this field varies directly with the instantaneous voltage applied to the transformer primary winding. These variations, coupled to the secondary windings, produce the desired output voltage. Since the transformer appears to the source as an inductance in parallel with the (equivalent) load, the primary will appear as a short circuit if dc is applied to it. The unloaded inductance of the primary must be high enough so as not to draw an excess amount of input current at the design line frequency (normally 50 or 60 Hz). This is achieved by providing sufficient turns on the primary and enough magnetic core materials so that the core does not saturate during each half-cycle.

To avoid possibly serious overheating, transformers and other electromagnetic equipment designed for 60 Hz systems must not be used on 50 Hz power systems unless specifically designed to handle the lower frequency.

5.4 Batteries and charging

The availability of solid-state equipment makes it practical to use battery power under portable or emergency conditions. Hand-held transceivers and instruments are obvious applications, but 100 W output transceivers may be practical users of battery power (for example, emergency power for HF transceivers).

Low-power equipment can be powered from two types of batteries. The *primary* battery is intended for one-time use and is then discarded; the *storage* (or *secondary*) battery may be recharged many times.

A battery is a group of chemical cells, usually connected in series to give some desired multiple of the cell voltage. Each assortment of chemicals used in the cell gives a particular nominal voltage. This must be taken into account to make up a particular battery voltage. For example, four 1.5 V carbon-zinc cells make a 6 V battery and six 2 V lead-acid cells make a 12 V battery.

5.4.1 Battery capacity

The common rating of battery capacity is ampere-hours (Ah), the product of discharge current and time. The symbol *C* is commonly used; C/10, for example, would be the current available for 10 hours continuously. The value of C changes with the discharge rate and might be 110 at 2 A but only 80 at 20 A. Capacity may vary from 35 mAh for some of the small hearing aid batteries to more than 100 Ah for a size 28 deep-cycle storage battery.

Sealed primary cells usually benefit from intermittent (rather than continuous) use. The resting period allows completion of chemical reactions needed to dispose of by-products of the discharge.

The output voltage of all batteries drops as they discharge. "Discharged" condition for a 12 V lead-acid battery, for instance, should not be less than 10.5 V. It is also good to keep a running record of hydrometer readings, but the conventional readings of 1.265 charged and 1.100 discharged apply only to a long, low-rate discharge. Heavy loads may discharge the battery with little reduction in the hydrometer reading.

Batteries that become cold have less of their charge available, and some attempt to keep a battery warm before use is worthwhile. A battery may lose 70% or more of its capacity at cold extremes, but it will recover with warmth. All batteries have some tendency to freeze, but those with full charges are less susceptible. A fully charged lead-acid battery is safe to –26 °C or colder. Storage batteries may be warmed somewhat by charging or discharging. Blow touches or other flame should never be used to heat any type of battery.

A practical discharge limit occurs when the load will no longer operate satisfactorily on the lower output voltage near the "discharged" point. Much gear intended for "mobile" use may be designed for an average of 13.6 V and a peak of perhaps 15 V, but will not operate well below 12 V. For full use of battery charge, the gear should operate well (if not at full power) on as little as 10.5 V with a nominal 12 to 13.6 V rating.

Somewhat the same condition may be seen in the replacement of carbon-zinc cells by NiCd storage cells. Eight carbon-zinc cells will give 12 V, while 10 for the same voltage. If a 10-cell battery holder is used, the equipment should be designed for 15 V in case the carbon-zinc units are plugged in.

5.4.2 Primary batteries

One of the most common primary-cell types is the alkaline cell, in which chemical oxidation occurs during discharges. When there is no current, the oxidation essentially stops until current is required. A slight amount of chemical action does continue, however, so stored batteries eventually will degrade to the point where the battery will no longer supply the desired current.

The alkaline battery has a nominal voltage of 1.5 V. Larger cells capable of production more milliampere hours and less voltage drop than smaller cells. Heavy duty and industrial batteries usually have longer shelf life.

Lithium primary batteries have a nominal voltage of about 3 V per cell and by far the best capacity, discharge, shelf life and temperature characteristics. Their disadvantages are high cost and that they cannot be readily replaced by other types in an emergency.

The lithium-thionyl-chloride battery is a primary cell and should not be recharged under any circumstances. The charging process vents hydrogen, and a catastrophic explosion can result. Even accidental charging caused by wiring errors or a short circuit should be avoided.

Silver oxide (1.5 V) and mercury (1.4 V) batteries are used where nearly constant voltage is desired at low currents for long periods. Their primary application is in small equipment.

Primary batteries should not be recharged for two reasons: It may be dangerous because of heat generated within sealed cells, and even in cases where there may be some success, both the charge and life are limited. One type of alkaline battery is rechargeable and is so marked.

5.4.3 Secondary batteries

The most common type of small rechargeable battery is the nickel-cadmium (NiCd), with a nominal voltage of 1.2 V per cell. Carefully used, these are capable of 500 or more charge/discharge cycles. For long life, the NiCd battery should not be fully discharged. Where there is more than one cell in the battery, the most-discharged cell may suffer polarity reversal, resulting in a short circuit or seal rupture. All storage batteries have discharge limits, and NiCd types should not be discharged to less than 1.0 V per cell. Nickel cadmium cells are not limited to "D" size and smaller cells. They also are available in large varieties ranging to mammoth 1 000 Ah units having carrying handles on the sides and top for adding water, similar to lead-acid types. They are used extensively for uninterruptible power supplies.

For high capacity, the most widely used rechargeable battery is the lead-acid type. In automotive service, the battery is usually expected to discharge partially at a very high rate and then to be recharged promptly while the alternator is also carrying the electrical load. The most appropriate battery for extended high-power electronic applications is the so-called "deep-cycle" battery. These batteries may furnish between 1 000 and 1 200 Wh per charge at room temperature. When properly cared for, they may be expected to last more than 200 cycles. They often have lifting handles and screw terminals, as well as the conventional truncated cone automotive terminals. They may also be fitted with accessories, such as plastic carrying cases, with or without built-in chargers. Lead-acid batteries are also available with gelled electrolyte. Commonly called "gel cells", these may be mounted in any position sensitive.

An automotive lead-acid battery was designed for one task: to deliver a lot of current for a brief period of time. Its output voltage does not remain constant during its discharge cycle, and it is not a good idea to discharge it completely. An automobile battery will not tolerate too many deep-discharge cycles before it's ruined.

A deep-discharge lead-acid battery is much better suited emergency power needs. It can be discharged repeatedly without damage, and will maintain full output voltage over much of its discharge cycle. This type of battery is available at automobile- and marine-parts supply outlets. They are not much more expensive than regular automobile batteries and are designed to deliver moderate current for long periods of time.

The nickel metal hydride (NiMH) battery is similar to the NiCd, but the cadmium electrode is replaced by one made from a porous metal alloy that traps hydrogen; therefore the name of metal hydride. Many of the basic characteristics of these cells are similar to NiCds. For example, the voltage is very nearly the same, they can be slow-charged from a constant current source and they can safety be deep cycled. These are also some important differences: They have higher capacity for the same cell size often nearly twice as much as the NiCd types. The typical size AA NiMH cell has a capacity between 1 000 and 1 300 mAh, compared to the 600 to 830 mAh for the same size NiCd. Another advantage of these cells is a complete freedom from memory effect. NiMH cells do not contain any dangerous substance, while both NiCd and lead-acid cells do contain quantities of toxic heavy metals.

The Lithium-ion (Li-ion) cells is another possible alternative to the NiCd cell. For the same energy storage, it has about one third the weight and one half the volume of NiCd. It also has a lower self-discharge rate. Typically, at room temperature, a NiCd cell will lose from 0.5 to 2% of its charge per day. The lithium-ion cell will lose less than 0.5% per day and even this loss rate decreased after about 10% of the charge has been lost. At higher temperature the difference is even greater. The results are that Lithium-ion cells are a better choice for standby operation where frequent recharge is not available. One major difference between NiCd and Li-ion cells is the cell voltage. The nominal voltage for NiCd cell is about 1.2 V. For the Li-ion cell it is 3.6 V with a maximum cell charging voltage of 4 V. Li-ion cells cannot be substituted directly for NiCd cells. Chargers intended for NiCd batteries must not be used with Li-ion batteries, and vice versa.

5.5 Inverters

One source of ac power for use in the field is a dc-to-ac converter, or more commonly, an inverter. The ac output of an inverter is a usually square wave. Therefore, some types of equipment cannot be operated from the inverter. Certain types of motor are among those devices that require a sine-wave output. Aside from having a square-wave output, inverters have some other traits that make them less than desirable for field use. Commonly available models do not provide a high power handling capability. Higher power models are available but are quite expensive.

5.6 Generators

For long-term emergency operation, a generator is a requirement. The generator will provide power as long as fuel is available. Proper care is necessary to keep the generator operating reliably, however.

For these periods when the generator is shut down, battery power can be used until the generator can be reactivated. The lubricating oil level should be checked periodically.

If the oil sump becomes empty, the engine can seize, putting the station out of operation and necessitating costly engine repairs.

Remember the engine will produce carbon monoxide gas while it is running. The generator should never run indoors and should be placed away from open windows and doors to keep exhaust fumes from coming inside.

Generators in the 3-5 kW range are easily handled by two people and can provide power for radios and other electrical equipment. Most generators provide 12 V dc output in addition to 120/240 V ac.

Some generators have a continuous power rating and an intermittent power rating. If the total station requirement exceeds the available generator power, transceivers draw full power only while transmitting and that they are not going to be transmitting 100% of the time. It is necessary to ensure that the total possible power consumption does not exceed the intermittent power rating of the generator.

Generators should be tested regularly. Fuel should be fresh. Operator level maintenance (tune-up or oil change) should be performed regularly. Spark plugs should be checked carefully and spare spark plugs should be maintained. The air cleaners should be checked and cleaned according to manufacturer's instructions.

The generator should be checked for proper operation. If there are any fuel leaks, it should be turned off immediately and the problem corrected. The muffler should be inspected. All protective covers should be in place. The output voltage should be tested. If the generator does not have a built-in over-voltage protector, the voltage should be correct before applying power to radio equipment.

Finally, the generator should be checked for radio noise. Some generators are not fully suppressed for ignition noise. If there is a problem, it may be possible to use resistor-type spark plugs or spark-plug wires. A good Earth ground with a ground rod may help minimize noise.

5.6.1 Installation considerations

Any internal combustion engine is noisy and bothersome when communication equipment is being operated nearby. The placement of a power plant is important, regardless of its size. An engine running at 3 600 rotations per minute, even with an efficient muffler system produces noise and vibration. The engine vibrations are conducted thought the base upon which the engine is mounted to the ground or walls of the building housing the system. Brick or concrete-block construction will reduce the noise level, but if the generator shack is metal, there is less noise abatement. Metal panels may vibrate in sympathy with the sound source add to the din. Applying a hardening caulking compound to the vertical edges of the metal panels cab eliminate some of the noise, as can the use of sound-deadening material in lining the shack.

The distance between the alternator and the operating must be considered. Sound intensity varies inversely with the square of the distance from the source. The noise at a distance of 20 meters will be one-fourth that at a distance of 10 meters. At 30 meters, it will be one ninth.

Fuel consumption must be considered, both from an installation aspect and as a safety problem. Fuel will be used at the rate of 2 to 4 litres per hour is a 2.5-5 kW generator. There should be an ample reserve plan of at least 48 hours of operation. If the fuel is gasoline, safe storage can be a problem. Store gasoline in an area separate from the area housing the generator. Transfer only enough fuel at one time to fill the power unit's tank. If you in an area where propane or natural gas are available, it might be worthwhile to consider these options as a fuel source. Some alternators are supplied with multiple-fuel capabilities (gasoline or natural gas/propane). A special carburetion system is required for natural gas or propane.

5.6.2 Generator maintenance

Proper maintenance is necessary to obtain rated output and long service life from a gasoline generator. A number of simple measures will prolong the life of the equipment and help maintain reliability.

The manufacturer's manual should be the primary source of maintenance information and the final word on operating procedures and safety. The manual should be thoroughly covered by all persons who will operate and maintain the unit.

Fuel should be clean, fresh and of good quality. Many problems with gasoline generators are caused by fuel problems. Examples include dirt or water in the fuel land old, state fuel. Gasoline stored for any length of time changes as the more volatile components evaporate. This leaves excess amount of varnish-like substances that will clog carburetor passages. If the generator will be stored for a long period, it is good to run it until all of the fuel is burned. Faulty spark plugs are a common cause of ignition problems. Spare spark plugs should be kept with the unit, along with tools needed to charge them.

5.6.3 Generator earth ground

A proper ground for the generator is necessary for both safety reasons and to ensure proper operation of equipment powered from the unit. Most generators are supplied with a three-wire outlet. Some generators require that the frame be grounded also. An adequate pipe or rod should be driven into the ground near the generator and connected to the provided clamp or lug.

5.7 Solar power

A solar cell is a very simple semiconductor. Solar cells are, in fact, large-area semiconductor diodes. Simply explained, when the photons contained in light rays bombard the barrier of this semiconductor, hole electron pairs inside this P-N junction are freed, resulting in a forward bias of the junction, just as in phototransistors. This forward-biased junction can deliver current into a load. Because the exposed area of a solar cell can be quite large, the forward current proceed can be substantial. It follows that the output current of a photocell is directly proportional to the rate of photon bombardment, and thus to the exposed are of the photocell.

5.7.1 Types of solar cells

Originally, solar cells were made by cutting slides of grown silicon-crystal rod and subjecting them to doping and metallization process. These solar cells are called monocrystalline cells because each unit consists of only one crystal plate. The shape of these cells is the same as that of the silicon rod from which they are cut: round. A slice of this material with an area of 50 mm can be made into one photocell, but a slice of this size could also be used to produce upwards of a thousands transistors.

Most are polarity protected with a diode in series with the positive voltage line. When it gets dark, and the output voltage drops, the diode ensures that the panel won't start drawing current from the battery.

Solar panels typically deliver 15 to 18 V at 600 to 1 500 mA in full sunlight. This will not damage a high-capacity battery, such as a deep-cycle unit. All you need do is hook up the battery, put the solar panel in full sunlight, and charge away. The battery will regulate the maximum voltage from the panel.

If you're going to use a solar panel to recharge a smaller battery, such as a Nickel-Cadmium (NiCd) battery or gelled-electrolyte lead-acid battery, you'll need to pay a bit more attention to detail. These types of batteries can suffer damage if charged too quickly, so a regulated charge is necessary.

A dc-ac converter, or inverter converts 12 V to a square-wave ac output at approximately 60 Hz. Inverters are limited to about 100 to 400 watts, however, and some equipment (especially motors) cannot be powered by a square wave. An inverter will run a few light bulbs or a small soldering iron and can be a useful addition to a battery-operated station. Some newer ones use switching technology and are quite lightweight.

Polycrystalline cells are typically manufactures as rectangular blocks of seemingly randomly arranged silicon crystals from which the cell plates are cut. These cells are recognized by their shape, random pattern and colourful surface. Polycrystalline cells are less expensive to manufacture than monocrystalline cells. Reliable amorphous panels are available from many manufactures. These panels come in several forms: mounted on thin glass, framed, and even mounted on flexible substrates, such as steel.

5.7.2 Solar cell specifications

Depending on construction, each cell has an open-circuit, when exposed to the sun, of 0.6 to 0.8 V. This output voltage drops somewhat when current is drawn from a solar cell. This is called the cell's *load curve*. Open-circuit voltage is approximately 0.7, and output voltage at optimum load is normally 0.45. Output current is maximum with shorted output terminals. This maximum current is called the short-circuit current, and is dependent on the cell type and size. Because a cell's output current remains relatively constant under varying load conditions, it can be considered to be a constant-current sources.

As with batteries, solar cells may be operated in series to increase output voltage, and/or in parallel to increase output-current capability. Several manufactures supply arrays or panels with a number of cells in a series-parallel hook-up to be used, for example, for battery charging.

Techniques have been developed for the construction of amorphous cells whereby the cells are manufactured in series by cutting metal layers that have been vapour deposited on the amorphous silicon mass. This cutting is done with a laser. Cell width is such panels may be up to several feet, and the output-current capability of these relatively economical panels is excellent.

Solar-cell efficiency varies: Monocrystalline cell have efficiencies up to 15%; polycrystalline cells, 10 to 12%; amorphous cells, 6.5 to over 10%, depending on the manufactures process.

The output power of solar arrays or panels is specified in watts. Typically, the listed wattage is measured at full exposure to sunlight, at a nominal potential of 7 V for a 6-V system, 14 V for a 12-V system, and so on. You can calculate the maximum current that can be expected from a solar panel by dividing the specified output power by the panel voltage.

5.7.3 Storing solar energy

Because the sun does not shine 24 hours per day at many locations, some means of storing collected energy must be used. Batteries are commonly used for this purpose. Battery capacity is generally expressed in ampere-hours (Ah) or milliampere-hours (mAh). This rating is simply the product of discharge current and discharge time in hours. For example, a fully charge 500-mAh NiCd battery of good quality can deliver a discharge current of 100 mA for a period of 5 hours, or 200 mA for 2½ hours before recharging is required. Three types of rechargeable batteries are commonly used:

Nickel-cadmium (NiCd) batteries: NiCd are mostly used in relatively low energy applications such as hand-held transceivers, scanners, etc. The development of consumer electronics has contributed to the rapidly increasing availability (and somewhat-less-rapidly decreasing cost) of NiCd. Major advantage of NiCd: They are hermetically sealed, operate in any position and have a good service life (several hundred charge/discharge cycles), if they are properly maintained.

Gelled-electrolyte lead-acid batteries: These hermetically sealed batteries are available in capacities from below 1 Ah to more than 50 Ah. They are ideal for supplying energy to a radio station, but their cost (for capacities above 10 Ah) is rather high. For portable and low power stations, thought, this type of battery is difficult to beat. The cells can be operated in any position, but should be charged in an upright position. If properly maintained (no deep discharges-cell polarity reversal is possible under these conditions-and they stored in a fully charged state), gel cells last a long time (500 or so cycles).

Other lead-acid batteries: These are available in the standard automotive version, in the marine/recreational vehicle deep-discharge version and in the golf-cart variety. Differences: Automotive batteries usually fail (because of the thin plate and insulation material used in their construction), resulting in premature internal short circuits. Golf-cart and marine/recreational vehicle batteries have thicket plated with more rigid insulation between them, so these batteries can with stand deeper discharge without plate deformation and internal failure. Deep discharge batteries provide the best value in a ham station. Some of these batteries require attention (the electrolyte level must be maintained), and they last longest when kept charged. Because these batteries use a wet electrolyte (water), and most of them are not hermetically sealed, they must be kept upright.

5.7.4 A typical application

Here's a practical example of how to calculate power requirements for a solar-powered HF radio station. The first thing to do is define the power demand. Assume a 100-W transmitter. The assumption is that 100 W is the peak power consumption, and occurs only during CW operation and SSB voice peaks when a 13.6-V nominal supply (a fully charged battery) is provided.

The most reliable way to calculate realistic power requirements is to determine the power used over a longer period of time (say) a week or month. Because most of us have more or less recurring weekly habits, we'll take one week as the base period. (One can substitute numbers to adapt this calculation for the transmitter, under typical operating circumstances.) Assume that the transmitter is turned on five days. Of each two-hour period, 1½ hours is spent listening, and transmitting takes the remaining half hour. Assume that the current consumption of the transceiver during receive is 2 A; during the 100-W peaks on transmit, current drawn is 20 A. The owner's manual for transmitter should give the maximum dc current drain. The average current consumption during SSB transmitting is only about 4 A. Therefore, we need a battery that can supply a peak current of at least 20 A and an average current of 4 A. Now calculate the total energy consumed in ampere hours over a one-week period:

Receiving: 2 A × 2½ hours/day × 5 days = 25 Ah

Transmitting: 4 A × ½ hours/day × 5 days = 10 Ah

The total energy used per week is 25 + 10 = 35 Ah, or per day (average) is 35 ÷ 7 = 5 Ah. If we had a perfect system, all we would need to do is supply 35 Ah per week (5 Ah per day) to the battery. In practice, imperfections in battery construction cause some loss (self discharge), for which the charging system must compensate.

Next, calculate the minimum battery capacity required for this application. The system should be designed so that sufficient energy is available to run the equipment for two consecutive sunless days (this is rather arbitrary – some locations are worse than others in this regard). Because these sun less days could be days on which operation is necessary and because it is not good to discharge a battery to less than 50% of its capacity (for maximum battery life), this battery must have a capacity of lest 2 (days) × 5 Ah) ÷ 0.5 (for the 50% charge capacity left after 3 days without sunshine) = 20 Ah. If the location is likely to be without sunshine for as much as an entire week, the battery requirement would be 7 × 5 ÷ 0.5 = 70 Ah. Add about 10% to this number to compensate for self-discharge and other losses. (Typically, this means to procure the next-larger-size battery than the initial calculations indicated.)

To keep the battery sufficiently charged, firstly estimate the average number of hours of sunshine per year in the area. This information can be found in an almanac. As a guide, average annual sun exposure is approximately 3 200 hours per year in sunny regions, less elsewhere (down to about 1 920 hours per year in the far northern climates).

The solar panel should be mounted in a fixed position with an optimum angle relative to the Earth. In temperate zones, it could vary from about 30° in the summer up to about 60° in winter. Fixed-mounted solar panels cannot pick up maximum energy from the sun, for obvious reasons. In practice, they receive only 70% of the total sunlit time, which is anywhere between 1 340 and 2 240 hours per year (between 26 and 43 hours per week), depending on location.

The remaining system planning is easy. Earlier calculations showed that the solar cells must replenish 35 Ah per week, plus 10% to compensate for losses, or about 38.5 Ah or battery capacity. With solar energy available in the Sunbelt for 43 hours per week, the required charge current is 38.5 Ah ÷ 43 hours of sunshine = 0.9 A. In the northern part of the US, this is 38.5 Ah ÷ 25.8 hours = 1.5 A.

In the 12-V system described here, the solar panel operates, with a fully charged battery at about 13.6 V, plus the voltage drop of a series diode. With a fully loaded panel voltage of 14 V, a panel rated at 21 W (14 V × 1.5 A) is required in northern climes. In practice, this power can be obtain from good quality solar panel with a surface area as small as 65 cm^2. In sunny regions only 12.6 W (14 V × 0.9 A) of solar energy may be needed.

5.7.5 Some practical hints

Solar panels can be wired in series to provide increased output voltage. If the total output of the cell array exceeds 20 V, shunt diodes may be wired across each solar cells. Similarly, solar panels can be wired in parallel to yield increased output-current capability.

A series diode should be installed to prevent discharge of the battery into the panels. A Schottky diode can be used in applications where it is important to maintain the lowest voltage drop (and minimum loss of charge current).

Precaution should be taken to prevent battery overcharging and related gas discharge inside the battery. Several manufacturers supply simple charge regulators that serve this purpose by disconnecting the solar panel from the battery when the battery is fully charged. Some of these chargers allow charging to resume when the battery has reached a measurable level of discharge.

Note: These values are only valid for lead-acid batteries; and entirely different set of charge criteria exists for NiCds.

5.7.6 Installing solar panels

If you plan to permanently install solar panels, consider mounting them at ground level on a simple wooden or metal frame, or mounting the m on the roof. Roof mounting is more appropriate if you have a roof that slopes at the correct angle (30-60°), and in the right direction (anywhere between a kittle east of south and southwest is acceptable). The easiest way to mount panels permanently is with a silicone adhesive. First, series diodes should be mounted on the back of each panel.

If the solar panels are going to be located in an area where they might be subjected to lightning, it is especially important to ground the metal frames of the solar panels. A separate wire should be used for this Earth ground, that is, not combined with one of the power leads.