Designing Solar Power Systems for FM Translators

by Bill Sepmeier

Generally speaking, most translators are common enough, used to provide FM service where reception is poor and to expand a station's reach. Generally translators usually are located at sites which receive commercial power.

OFF-THE-GRID DESIGN

However, with many translators running 40 Watts of RF output power or less, solar power has emerged as a reasonable option that allows their placement anywhere service is desired, regardless of power availability.

Station engineers can design their own solar systems or choose from new lines of mostly pre-assembled systems, such as the Satcom Resources' iPowerPV™, a fully-integrated solar power plant designed to deliver "plug and play" solar energy for many types of telecommunications equipment in the most remote of remote locations.

Solar modules after installation on a three-module iPowerPV.

As a bonus, the system not only catches the sun, but also shades the system.

For example, the US Naval Research Lab chose an iPowerPV to power a "plug and play" high-speed satellite and WiFi Internet connectivity setup for a genetics lab in Sierra Leone, part of an effort to cut the time required to identify dangerous new diseases.

LOCATING A VIABLE SITE

The design of any off-grid power system begins with the collection of some basic data. Among the things it is important to know are:

- if the site is generally sunny all day long.
- how severe the shading of the site is during the day.
- the load in Watts presented by the translator.
- the "peak insolation time," or number of "peak sun hours" available at the site.

("Peak Sun" is the number of hours each day that the site receives energy from the sun at roughly 1 kW per square meter, averaged over a year's time. This information has been gathered over many years by NOAA and other climate monitoring agencies around the world.)

CALCULATING THE LOAD

We wanted to place a Tepco J-340 translator on a mountaintop overlooking Vail, Colorado. In order to know how many photovoltaic (PV) modules we will need, we have to determine how many Watt-hours of energy the translator will draw.

According to the documentation, the J-340 draws 2.8 Amperes when powered by 28 Volts DC, which equals 79 Watts from the battery, so we multiply 79 Watts by 24 hours to find that the daily load is 1,896 Watt-hours. (If you have the tools to measure the current yourself, it is a good idea to do so – the actual draw is often less than specified.)

From this point, solar array design can be performed two ways. We can stay in Watts and Watt-hours or convert to Amperes and amp-hours. When all solar modules delivered 12 VDC, most designers used amp-hours. Today's solar modules often deliver much higher voltages which, though the use of a "Maximum Power Point Controller," can be converted to any battery voltage required. For purpose of illustration, we will stay in Watts for the moment.

FACTORING THE SUN YIELD

In any solar off-grid application, the battery actually powers the load, not the solar modules. Thus the solar modules must provide the battery with enough energy to power the translator 24 hours a day, recharge the battery while to translator is operating, and do this all while the sun is shining.

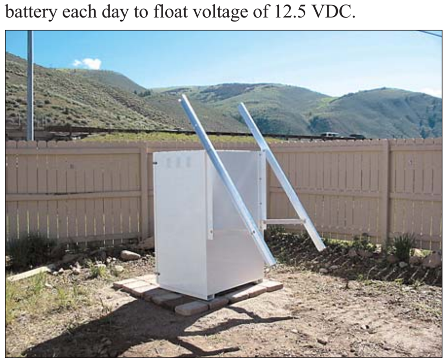
During the conversion from electricity to chemical and back, batteries lose about 20% of the energy input to them. Because of this loss, we multiply the 1,896 Watt-hours of actual load by a factor of 1.2, which makes the effective energy requirement 2,276 Watt-hours.

Since according to NOAA the sun averages 5.5 hours of 1000 W/m insolation at our proposed site above Vail, this is the length of time the PV modules will have, on average, to produce the 2,276 Watts the battery requires to recharge. By dividing the energy needed over 24 hours by 5.5 we learn that we need 414 Watts per peak sun hour. ("Always Round Up" is the cardinal rule of off-grid solar design – remember, winter days are shorter than average days!)

BUILDING THE SYSTEM

It is time to choose among solar modules, which vary in power output, to find out how many we will need to maintain our battery.

In this example, we will choose a relatively inexpensive module that happens to provide 12.5 VDC, a Mitsubishi 125-Watt module. Dividing the effective load per peak sun hour (414 W) by the module's power (125 W), we find that four of these modules will operate this load and charge the battery each day to float voltage of 12.5 VDC.



Powder coated aluminum iPowerPV solar shelter with an integrated solar module rack in place.

Since we are running a 24 to 28 Volt load and battery, we have to wire two modules in series. Therefore, eight of these 125-Watt modules, four strings of two, will deliver the energy the load and battery require.

Of course, solar modules today can deliver a lot more than 125 Watts per module – 185 to 210-Watt modules are common, but they operate at higher voltages and require the use of a "Maximum Power Point" (MPPT) charge controller that can output proper battery charging voltages. These controllers cost less than one PV module, though, and by using one we could use three of these newer 30 Volt, 185-Watt modules instead of eight 125-Watt units, (though four, in two series/parallel strings, would be recommended for optimal charge controller operation), saving far more than the cost of the charge controller.

Wiring the solar PV modules after they are mounted on integrated aluminum rack assembly.

RESERVE CHARGE

Since every day is not sunny, the battery must provide energy for operation during cloudy weather. Again, we need some information. How many "cloudy days" or days of autonomy are needed? Conservative designers generally prefer a week of autonomy, so let us choose seven days as our autonomy goal.

Unlike starting batteries used in vehicles, solar system batteries are designed to be discharged and recharged many times, and are called "deep cycle" batteries for this reason. Battery manufacturers, however, do not design them to be run all the way down all of the time. 50% of a full charge is typically the most discharge these batteries expect to see on a recurring basis.

"Less (discharge) is More", as someone once said, and you can run them into the ground occasionally without too much damage, but they will live their expected lifetime and resist freezing in the winter if 50% discharge levels are their regular diet.

SIZING UP THE BATTERIES

At this point we need to convert the load from Watt-hours to amp-hours using Ohm's Law. To be conservative, we use the current drawn at the 50% battery discharge level of 24 Volts instead of the manufacturer's specified load at 28 Volts – the float voltage.

Rounding up as we go, the effective load becomes about 95 amp-hours; multiply 95 amp-hours by 7 days and the effective solar autonomy load is 664 amp-hours per week at 24 VDC. Since we do not want the battery to deliver more than 50% of its storage capacity, this site will require a battery with a minimum total reserve capacity of 1,328 amps.

Battery storage capacity is generally specified at various rates of discharge, the most common being the 100 and 20-hour discharge rates, which imply the current drawn to discharge the battery over these lengths of time. Without conversion loss, the J-340 translator's 2.8 amp per hour load will actually take about 475 hours to fully discharge a 1,328 amp-hour battery, or about 237 hours to run it halfway down.

Real-world conversion loss subtracts about two days of reserve power a perfect battery could deliver. But since batteries are generally sold assuming higher current loads, you still can buy too many, since in low-power load applications they will be under-rated even at the 100 hour rate.

SOLAR BATTERY TYPES

There are three basic types of deep-cycle solar batteries: flooded wet cells that use a water and sulphuric acid electrolyte (which requires regular maintenance but provides a large storage capacity), AGM "glass mat" cells in which the electrolyte is held in a sponge of fiberglass, and gel cells in which the electrolyte is in a gel form.

Most off-grid applications today use sealed, "maintenance-free" AGM "glass mat" batteries, since the electrolyte solution is suspended in a fiberglass mat between the plates and does not stratify like "flooded wet-cell" battery water does. This eliminates the need for most battery service, such as adding distilled water and regular equalization charging to break down sulphates on the plates.

The iPowerPV solar plant is the only pre-fab power station that uses modular AGM batteries designed to provide primary power for telephone company central offices instead of the typical solar site's large series-parallel arrays of "8D" AGM batteries. The iPowerPV also includes a temperature-compensated battery charge controller, DC and AC circuit breakers, and dual 125W pure sine wave inverters (a "cold-spare" is standard).

There are many reasons to incorporate these types of modular batteries. First, they store a lot more energy in much less space. They use nickel-plated copper buss bars to connect their modular cells in series and parallel instead of bulky 4/0 jumper cables. And they are racked

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in enclosed steel cases to prevent battery damage, especially in seismic areas. They do not off-gas nearly as much corrosive vapor or hydrogen since they do not have to be equalized.

The 12 VDC, 1470 amp-hour modular AGM battery iPowerPV batteries and pre-assembled solar electronics. The 19" rack for customer equipment is located at the top of the enclosure.

If we were "home brewing" though, we might use the more "conventional" design – the largest capacity battery available in a 12-Volt AGM format, the MK or DEKA "8D." These batteries are rated for 245 amp-hours at their 100 hour rate to full discharge. Using the published 100 hour rate, 245 amp-hour capacity per battery to obtain the 664 amp-hours (to a 50% discharge) that our effective load needs for a week's autonomy, it will require 12 of these batteries connected in series-parallel, since we need 24 to 28 Volts.

A DESIGN PROBLEM

This battery bank would require six batteries in parallel, twice in series, to deliver the 24 to 28 VDC and storage capacity needed. Off-grid solar operators have found that it is risky to go more than three batteries "deep" – or in parallel – since, over time, small discrepancies can appear in terminal connection resistance.

These irregularities cause imbalances between the batteries when they are recharged and lead to less battery bank capacity than expected – or even to premature battery failure. This is why telephone companies went with large capacity modular-buss batteries 100 years ago, still use them, and why they are well suited today for off-grid solar power systems.

We can perhaps get around this problem by calculating the battery's reserve capacity at 2.8 amps, the actual current our load will draw. A 245 amp-hour battery literally can provide energy for 245 hours if the load is 1 amp. At 2.8 amps it will last 87.5 hours, or 43.75 hours to 50% discharge. That is 1.83 days of backup time. Four batteries in parallel, in series-strings of two batteries will get the 24 to 28 Volts the translator needs. Thus eight 245 amp-hour batteries will back up our effective load for seven days.

Four deep is better than six, but still above the "three deep" parallel rule established by years of off-grid solar power users. If you use the sealed, modular Telco-grade system, these problems are eliminated.

AVOID GAMBLING ON THE SUN

Of course, the PV modules will generate some power during "non-peak" morning and evening hours – even on cloudy days.

The "cloudy day power" of about 30% of our 125-Watt module's rated output current of 7.23 amps is 2.17 amps. At 30% output four 125-Watt PV strings in parallel will make about 8 amps, depending on cloud density – which is more than the translator requirement of 2.28 amps. So on a cloudy day the array will operate the load for a few hours and still send some power back to the battery.

You can gamble and reduce the battery bank to two series strings of three in parallel. However, I would not give odds regarding whether you will win every time, or if your batteries will last their expected life of eight or nine years, since they may be discharged more than 50% far more often. Not as long as Murphy's Law is still on the books.

CHARGE CONTROL

Overcharging is the most common reason batteries fail in off-grid solar systems – or used to be, before the development of reliable charge controllers. Instead, keeping the solar modules within their optimal power window while optimally adjusting the voltage and current to the battery can produce 20% to 30% more power.

Today's charge controllers come in two flavors, standard PWM (pulse width modulation) and MPPT (maximum power point). PWM controllers are less expensive and provide the proper voltages needed to charge and protect the battery. MPPT controllers can utilize higher voltage PV modules and match them to lower voltage battery banks.

Such controllers optimize the recharging requirement of the battery against the varying power input solar panels generate with varying levels of insolation throughout the day. Voltage and current are optimized to the battery while the solar modules are allowed to remain in the range of voltage and current that is optimal for solar cell power production, instead of being "locked" to the battery bank's voltage – this is how they can provide up to 30% more energy to the battery and load.

TOTAL SITE LOCATION FLEXIBILITY

Solar energy provides complete flexibility in choosing translator and other low-power communications sites at reasonable costs, especially when compared to bringing in commercial power.

In this example we have used a DC powered load, but pure sine wave inverters are inexpensive, reliable and can operate standard 120 VAC devices with negligible overhead power consumption. This makes the user's choice of equipment very simple. You easily can design a system to meet your site's needs, though there are a lot of choices for mounting hardware and parts that we have not covered here.

Or purchase a system that will arrive ready to build and run in less than a day, including up to six PV modules (125 to 225 Watts each), the racking assembly needed to mount the modules integrated on a weatherproof aluminum enclosure that holds the Telco-grade modular battery, solar electronics, redundant inverters, and even provides standard 19-inch rack space for your translator.

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