A Solar Powered Repeater for EmComm

Don't worry about keeping your repeater powered up in an emergency.

Dave Leavenworth, WV6JPL, and Pete Tiffany, KT4BW

The emergency communications aspects of Amateur Radio have always been important to most operators. Our ability to get the message through when other methods fail is what the public has come to expect from us. With this in mind, our local radio club, the Cumberland Plateau Amateur Radio Club (CPARC), recently undertook a project to convert the club VHF emergency repeater from commercial power, with battery backup, to solar power.

If we were to have a long power outage, so long that the station backup batteries were close to discharge, a means of recharging these batteries would be needed to keep the repeater on the air. New batteries or a gasoline powered generator could be brought in. A better choice, as suggested by Repeater Trustee Paul Dorschel, W4EYJ, would be solar power, not just for times of commercial power outages, but as a replacement for ac mains power. This article describes the development of our club's solar powered VHF repeater located in Crossville, Tennessee.

CPARC Repeater Configuration

The CPARC 2 meter repeater is a Motorola Mitrek model T83 that uses a CAT 300 DX controller. Good coverage of the Cumberland County area is obtained by running at about 40 W into a Diamond vertical antenna mounted at a height of 50 feet.

Some might argue that the repeater modified as planned will not really be solar powered, but will be battery powered, with the battery charging and recharging accomplished by use of a photovoltaic (PV) panel. The authors leave it to the reader to decide if the electrons that activate the repeater come from the battery or the PV panel.

Funding

Solar equipment is not cheap. Although the cost per watt continues to decrease, PV panels remain an expensive item. In addition, batteries of 100-200 or more ampere hours (Ah) were needed along with sophisticated charge controllers. After an initial successful fund raising event, CPARC turned to our regional power company, Volunteer Energy Cooperative (VEC). The VEC, through their Customer SHARE Program, awarded a grant to CPARC that, when combined with club funds, gave us enough to proceed with this project. Without their assistance, this project could not have taken place. Thank you VEC! The awarding of the grant is shown in Figure 1.

KT4BW

Figure 1 — Receiving Volunteer Energy Cooperative grant from VEC. Left to right are Dick Chabot, KB3YR, CPARC president; VEC representative Jim Purcell, and coauthor KT4BW, solar project manager for CPARC.

The Plan

The use of solar power to run repeaters or other radio equipment is not new.[1-5] Most solar emergency power systems have the following elements in common: the PV panel(s), the charge controller, the battery(s) and a disconnect mechanism. A block diagram is shown in Figure 2. The capacity needed from the panel and battery plus the balance of these capacities was determined by power demand, peak loads expected, environment, cost and reliability.

As a starting point, we made

[1]Notes appear on page 33.

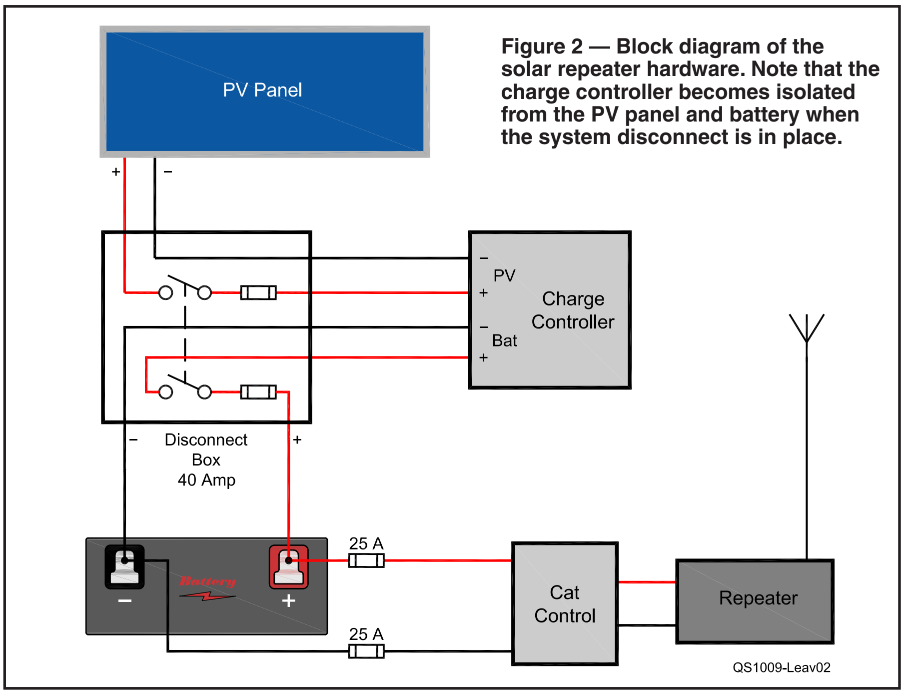

Figure 2 — Block diagram of the solar repeater hardware. Note that the charge controller becomes isolated from the PV panel and battery when the system disconnect is in place.

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some base assumptions. We chose 12 hours of key down transmissions from the repeater in each week, 500 mA of current needed to keep the repeater on the air during periods not in use, a maximum of five consecutive sunless days in our Tennessee weather and an average of 21 Ah per day while transmitting at 60 W. These data were entered onto a system sizing worksheet found in the *Solar Living Sourcebook*, 30th Edition.[6] A modified worksheet helped us to determine the necessary size and capacity of the panel and battery for our project and helped ensure that they would match each other when installed in the field.

Element Details

PV Panel

PV panels are available in a variety of sizes, styles, configurations and prices from a number of manufacturers. After a extensive search, we chose a Kyocera panel rated at 130 W. At $484, it seemed a good value. On sunny days, this panel should produce 7.4 A at 17.6 V.

Charge Controller.

Co-author WV6JPL lives off the grid in rural Cumberland County. He uses only solar and other non commercial sources of power. Using his experience and guidance, we initially chose a Xantrex model 35C charge controller for this project. This advanced controller can monitor the PV panel, the battery and the repeater demand to choose how best to distribute the power coming into the system. In addition, it features an optional data gathering accessory that monitors current, voltage and energy use on an instantaneous and cumulative basis. Unfortunately, the pulse width modulation (PWM) based Xantrex C35 turned out to generate so much RFI that it was unusable, even after repeated attempts at filtering.[7]

After a literature search, technical discussions with vendors and problem solving discussions within the club, we found that a newer, potentially better, charge controller technology was available. This was in the form of charge controllers using *Maximum Power Point Tracking* (MPPT) technology. A controller of this type, an MPPT500 manufactured by BZ Products was available to us for evaluation.

This controller worked properly and exhibited none of the RFI problems of the Xantrex unit.[8,9] Power from the PV panel comes to the controller at about 17 V. MPPT uses all the 17 V and so obtains a 20 to 30% increase in available charging current compared to PWM technology. The BZ controller we evaluated also had a battery temperature probe as a standard feature to help it adjust to differing ambient conditions, a useful tool during seasonal temperature swings. Data gathered using the BZ controller is limited compared to the Xantrex, as only instantaneous current and voltage readings are available. With no internal recording options, data must be collected by an external device as described later.

Battery

Batteries are expensive, heavy and potentially dangerous. These factors must be considered as part of the planning and implementation. Flooded cell, gelled electrolyte and glass mat batteries were studied. Lead/acid battery life is tied closely to number of charge/discharge cycles and to the depth of discharge. After consideration of each, AGM technology (Absorbed Glass Mat) was chosen. For good AGM battery life (greater than 750 charge-discharge cycles), maximum discharge should not exceed 50% of total battery capacity.[10,11] Based on the use parameters previously stated, this would mean that our repeater would require an AGM battery of 200 Ah, based on the standard 20 hour discharge rate. A 198 Ah Deka AGM battery as shown in Figure 3 was purchased for this project.

Equipment Installation

The solar panel, charge controller and AGM battery were installed at the CPARC repeater site. A solar panel mounting bracket was also purchased and attached to the antenna tower at the 30 foot level using a fabricated interface. For system and operator safety, a disconnect box with 40 A fuses was installed between the panel and the battery. As can be seen in Figure 2, it is wired so that if open, it will isolate the charge controller, the battery and the PV panel. Copper wire of #8 AWG was used for all current carrying runs. Figures 4 and 5 show site construction.

Elevation and azimuth positioning are important parameters for any solar panel as they help determine the capture efficiency of the panel. Depending upon geographic location, month of the year and time of the day, the optimum position for a PV panel will change.[12] We concluded that for small systems such as ours, mechanical sun tracking devices do not pay for themselves in overall increased efficiency of capture. We are located at a latitude of about 36° and have aimed our panel due south with a tilt using the popular algorithm of latitude plus 15° for a tilt of 51°. This tilt optimizes the panel position for the winter months.

When the PV panel, charge controller and battery were connected, the charge controller immediately sensed power from the solar panel. It continued to register battery

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Figure 3 — Selected battery for our system, a Deka 12 V, 198 Ah unit. This battery weighs 130 pounds. Insulated battery box designed and constructed by Joe Koester, W4NSA.

N7TRK

Figure 4 — Panel bracket installation by Al Perkins, KA1KIX, on left, assisted by KT4BW.

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Figure 5 — Construction at repeater site. Left to right: Dick, KB3YR, club president; Bill Melton, N4TRK, fabrication; coauthor WV6JPL, solar and Al Perkins, KA1KIX, tower work.

KT4BW

Figure 6 — 130 W PV panel on line in Tennessee.

charging until the float stage was reached at which point the charge current dropped to 0 A and the full charge voltage was registered at the charge controller. The system worked! Figure 6 shows our repeater site after installation. This was on October 23, 2009. The repeater has been on solar power exclusively since that date.

Data Collection

We needed actual usage data to evaluate our system and to help answer a number of questions, such as:

- How deep a discharge is there to the system battery during an average usage sunny day?
- How deep is the discharge during a cloudy day? a cloudy week?
- How deep a discharge after an hour weekly net (heavy usage) session?
- What is the voltage drop overnight due to repeater current drain?
- How fast is the recovery of the battery after daybreak?
- How much battery charging during a cloudy day? (There will be some.)
- Can we expect to limit maximum battery discharge to 50% (above 12.3 V)?

Enter the Data Logger by Velleman Instruments. This instrument, a four channel device, can collect system data on a continuous basis. It was configured to collect battery voltage data using the software included with the instrument. The data are stored and displayed on a PC using the *Windows* operating system. Both numerical and graphic data have been obtained. Figure 7 shows a trace of battery voltage taken over a period of 23 hours, sampling every 5 seconds. Note some of the interesting information obtained. One can "see" sunset, sunrise and a number of repeater usages during the early evening. At 7 PM, our local ARES® net was on for about 30 minutes. There are also regular hourly voltage spikes seen on the graph. These are audio repeater controller time announcements. Note there may have been some stray clouds during sunrise.

Conclusions

It has been an interesting technical journey to date and it will not be over nor will all questions be answered for some time. We are on the air, however, and the system appears to be running well. Long term battery life remains a concern and needs additional study. The goal of a reliable VHF communication medium during an extended power outage appears obtainable.

Not previously mentioned is the freedom we now have for repeater location because we are not dependent on commercial mains connectivity. We can thus choose a location based solely on desired coverage area.

See the QST-In-Depth Web site and visit **www.cparc.net** for further project information.

Future Plans

An important addition planned for our system is a low voltage cutoff for the battery. It would be wise to protect the battery in the event of the excessive drain that might occur during the worst of all conditions (simultaneous cloudy or rainy weather exceeding five straight days with very hot temperatures and heavy repeater usage). The cutoff would be set to activate when a preset voltage was reached.

The Data Tracker will be used to help define battery voltage profiles during a variety of operating and weather conditions.

It would also be advantageous to have a 24/7 reading and recording trace (wireless?) of battery voltage and other parameters. This could be done if sufficient funds became available, but there are no plans at this time.

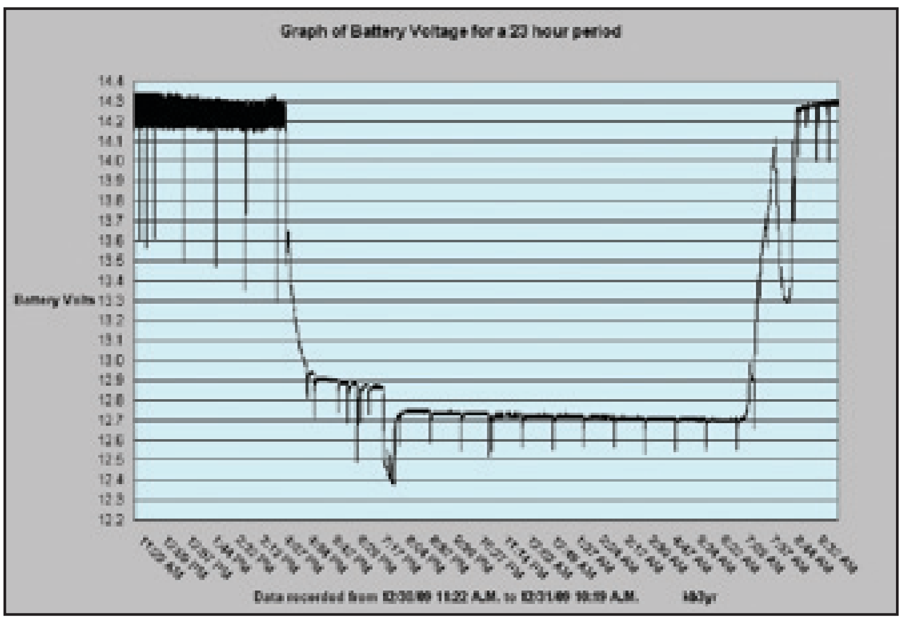


Figure 7 — Plot of battery voltage from Data Tracker taken over 23 hour period from December 30 to December 31, 2009. Graphic display developed by KB3YR.

Acknowledgments

This has been a club project that has involved most of our 30 CPARC members. The authors thank all who participated in fund raising, construction, publicity, purchasing and technical discussions and those who gave encouragement during this adventure.

Notes

[1]D. Casler, KEØOG, "Solar Power for Your Ham Station," *QST*, Apr 1996, pp 33-37.
[2]**www.qsl.net/va3pla**, solar powered repeater.
[3]**www.polkcounty.org/ham/repeater.htm**, solar powered repeater.
[4]P. McChesney, "Solar Electric Power for Instruments at Remote Sites," **geopubs.wr.usgs.gov/open-file/of00-128/of00-128.pdf,** 2000.
[5]M. Morris, WA6ILQ, "Some Thoughts on Off-The-Grid (Solar, Micro-Hydro or Wind Powered) Repeater Systems," **www.repeater-builder.com/tech-info/some-thoughts-on-solar-power.html**.
[6]J. Schaeffer, Editor, *Solar Living Sourcebook*, 30th Edition, Real Goods, Aug 2007, pp 171-176, 579-580.
[7]**www.ecodirect.com/what-is-a-pwm-charge-controller-s/144.htm**
[8]**www.arrl.org/qst-in-depth**
[9]**www.windsun.com/General/PV-EMI.htm; www.windsun.com/ChargeControls/MPPT.htm**
[10]See Note 8.
[11]**www.windsun.com/Batteries/Battery_FAQ.htm**
[12]**www.oksolar.com/technical**

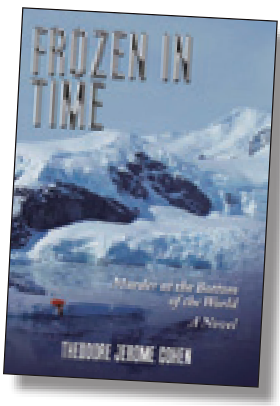
David Leavenworth, WV6JPL, was first licensed in the early '60s. For a variety of reasons, he was not active for the next 40 years, instead obtaining his degree in electronics and working in the field of optical coatings. Upon retirement and relocation to Tennessee in 2001, Dave picked up the urge again and passed his Amateur Extra class exam in 2008. Dave lives in rural Cumberland County and is off the grid. He uses a combination of solar, wind and diesel (backup) for 100% of his residential power needs. Dave is a member of CPARC, ARRL and ARES, and is a VE. Dave can be reached at **leavenworth@frontiernet.net**.

Peter Tiffany, KT4BW, was first licensed in 1992 after retiring to Tennessee in 1990 with his wife, Linda. Prior to this, Pete had spent 31 years in Michigan working in chemical research and development. He is currently a member of CPARC, ARRL, ARES and SATERN, and is a VE. Radio interests include chasing DX, the digital modes and emergency communications. Shortly after Katrina hit, Pete was part of the ARRL response, operating for the Red Cross in Gulfport, Mississippi. In addition to Amateur Radio, Pete plays euphonium in the local community band and rides his Harley every chance he gets. Pete can be reached at **kt4bw@arrl.net**.

New Products

FROZEN IN TIME — A NOVEL BY TED COHEN, N4XX

◊Nearly 50 years ago, Theodore J. (Ted) Cohen, N4XX, spent four months on a small peninsula jutting out of the North Antarctic Peninsula. There, he and another scientist from the University of Wisconsin-Madison conducted geological and geophysical studies throughout the 1961-1962 Austral summer. From time to time in those intervening years, Cohen thought about the many experiences they encountered as they moved among their various work sites on the Peninsula, the nearby offshore islands, and the Chilean bases in the South Shetland Islands...harrowing experiences that almost cost them their lives on several occasions.



The novel *Frozen in Time* chronicles how Cohen (the character Ted Stone in the novel) joined UW-M's Geophysical and Polar Research Center to assist a fellow scientist with collecting rock and fossil samples. Stone also will be conducting his own geophysical studies. Together, they travel to Punta Arenas, Chile, where they join the 16th Chilean Expedition to the Antarctic, which takes them Base Bernardo O'Higgins on the Antarctic Peninsula.

On that expedition are two Chilean Navy non-commissioned officers who robbed the Banco Central de Chile in Talcahuano following The Great Chilean Earthquake of 1960. The valuables they took from safe deposit boxes in the bank now are hidden in a crate that is on its way to Antarctica as well. Once the Expedition has been completed, that crate is to be shipped to the home of a friend of Chilean Army First Sergeant Leonardo Rodríguez, one of the two Navy non-coms assigned to Base O'Higgins for the duration of the Expedition.

When Sergeant Rodríguez fails to return from a seal hunt in the waters around the base, the two Chilean Navy non-commissioned officers become Lieutenant-Commander Cristian Barbudo's prime theft and murder suspects. Fearing he will die, Barbudo reveals the identity of his two suspects to Stone, thereby placing Stone's life in jeopardy. But who can Stone trust with this information, if it comes to that, to see justice done?

This story is a work of fiction based on real events that took place between 1958 and 1965. It is a tale of greed, betrayal, and murder — one in which the reader is given a window into the frozen world at the bottom of the Earth that few people ever will read about, much less experience. *Frozen in Time* is available from the ARRL Bookstore, ARRL order number 0098. Telephone 860-594-0355 or toll free in the US 888-277-5289, **www.arrl.org/shop**, **pubsales@arrl.org**.

ARGENT DATA SYSTEMS SIMPLEX REPEATER

◊The ADS-SR1 from Argent Data Systems is a multifunction voice recorder device that connects to virtually any handheld, base or mobile radio. The ADS-SR1 records incoming transmissions and retransmits them on the same frequency. It's intended for disaster response, home or campground use and any place where radio range needs to be extended without the cost and complexity of a traditional repeater. The ADS-SR1 can be operated in silent mode (repeating transmissions only when requested) to repeat a missed transmission or to check for missed calls. The ADS-SR1 can also be used for voice mail or for a beacon. The unit features 218 seconds total recording time and up to 10 voice announcements with independent timers. The unit features optional Morse code or voice identification and DTMF remote control for all functions. It requires two AA batteries or an external 4-28 V dc supply. Price: $89. For more information or to order, visit **www.argentdata.com**.