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Publication Number

FSEC-PF-317-97

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PV POWERING A WEATHER STATION FOR SEVERE WEATHER

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ABSTRACT

A natural disaster, such as Hurricane Andrew, destroys thousands of homes and businesses. The destruction from this storm left thousands of people without communications, potable water, and electrical power. This prompted the Florida Solar Energy center to study the application of solar electric power for use in disasters.

During this same period, volunteers at the Tropical Prediction Center at the National Hurricane Center (NHC), Miami, florida and the Miami Office of the National Weather Service (NWS) were working to increase the quantity and quality of observations received from home weather stations.

Forecasters at NHC have found surface reports from home weather stations a valuable tool in determining the size, strength and course of hurricanes.

The emerging science of mesoscale meteorology, to predict local area weather, requires receipt, in a timely manner, of a large volume of measured data.

Home weather stations appear able to record the required information with an adequate level of accuracy. Amateur radio, utilizing the Automatic Packet Report System, (APRS) can be used to transmit this data to weather service offices in virtually real time.

Many weather data collecting station s are at remote sites which are not readily serviced by dependable commercial power. Photovoltaic (solar electric) modules generate electricity and when connected to a battery can operate as a stand alone power system.

The integration of these components provides an inexpensive standalone system. The system is easy to install, operates automatically and has good communication capabilities.

This paper discusses the design criteria, operation, construction and deployment of a prototype solar powered weather station.

1. INTRODUCTION

Natural disasters, such as hurricanes, floods, and tornadoes destroy buildings, equipment, plants and lives. They destroy businesses and homes, while at the same time, disrupting the normal daily community routines, leave hundreds and even thousands of people without electrical service, functioning water and sewage systems, communications, and other services for days, even weeks. The Florida Solar Energy Center (FSEC) began studying the application of photovoltaics to disaster relief efforts in the after math of Hurricane Andrew in Miami. It was determined that for large scale disasters PV was the natural solution for many energy needs during recovery.

The National Hurricane Center (NHC), Miami, Florida is responsible for producing advisories for hurricane and tropical storm over a broad area stretching from Africa to the Hawaiian Islands.

The Miami Office of the National Weather Service (NWS) is responsible for predicting severe local weather in South Florida.

The work of both of these weather forecasting groups relies heavily on surface observations. The objective of volunteers at NBC is to increase the number of home weather stations providing supplemental reports for forecasters.

Volunteers at the National Hurricane Center joined forces with the Florida Solar Energy Center to design, build and test a portable standalone weather station. The objective was to substantially increase the volume and quality of rwasured data received from home weather stations to meet the needs of the weather forecasters.

Photovoltaic (PV) power systems are already a proven power source for remote sites and are now shown to be applicable for use in natural disasters, such as hurricanes. 'Mere is limited use of PV for powering government weather equipment, as most weather stations are at airports and sinfflar facilities. This project presented a new application for PV, home weather stations and packet amateur radio communications.

2. TROPICAL WEATHER PREDICTION

Forecasters at the NHC are responsible for forecasting tropical weather in a broad area reaching from Africa to near the Hawaiian Islands. They rely on radar, satellite imagery and observations collected by aircraft, ship and surface stations.

Particularly in remote areas, the volume of surface observations is limited.

Forecasters at NBC have found surface reports from home weather stations a valuable too] in determining the size, strength and course of hurricanes.

3. LOCAL SEVERE WEATHER PREDICTION

The emerging science of mesoscale meteorology, to predict local area weather, requires receipt, in a timely manner, of a large volume of measured data.

Budgetary and logistic constraints limit the number of NWS surface observation stations. In Florida, for example, there are just over I 00 government owned data collection sites.

4. PROTOTYPE DESIGN CRITERIA

To meet the needs of the NWS, a weather station is required to operate continuously, especially during severe weather and hurricanes. Weather stations need to be easily deployed and installed at any desired location. This mean the design must withstand high winds and heavy rains, bu also be portable. Besides needing a strong structure, the enclosure must prevent moisture and rain from damaging the electronic equipment.

Because these weather stations are to be operated mostly volunteers at varying locations, they needed to be self-contained, inexpensive and easy to use. To promote wide spread implementation, stations need to use off-the-shelf components for lower cost and easier maintenance.

The weather data needs to be measured continuously and transmitted periodically 24 hours per day from any location. A cost-effective means is needed to transmit rea time weather data from the weather station to the weather service.

Another consideration, is how to power the station. Ease of installation would prompt the station to be selfcontained. The use of only batteries would require periodically replacing when they are dead. Therefore, the power source needs to operate as a standalone unit from a constant energy source such as solar. Hurricanes can brin heavy overcast that can last for numerous days. Therefore the station will be required to operate for three to four day with little or no sun.

A minimum data set consisting of air temperature, wind, precipitation and barometric pressure needs to be transmitted to the forecaster for the weather station to be a valuable too]. The data needs to be date and time stampe for each location measured.

5. HOME WEATHER STATIONS

Weather information is mostly obtained from air and naval ports with weather station mounted on their facilities. Another typical source is from weather stations maintains for monitoring environmental effects for the Park Service, Department of Natural Resources, and Geological Survey Department. These organizations have some PV powered weather stations in remote locations. But these weather stations are of scientific grade and are expensive to build.

A weather station is an electronic device that can measure, collect and store environmental infon-nation. A typical weather station consists of sensors, measurement conversion devices, system processor, data storage, data display, data transmitter and a power supply.

Communication can be through a visual display or an electronic data link in serial format via direct connection to a computer or by telephone modem, radio or satellite uplink.

There are several uses for weather stations from scientific to process control to meteorological measurements. The difference between them is the degree of accuracy, the types of sensors and the data collection system. Also, scientific stations must meet calibration and measurement standards not required by home stations. As an example, a scientific weather station would measure temperature to within 0.01 degrees as compared to I degree for a station made for home use. Home weather stations appear able to record the required information to an adequate level of accuracy for this application for the NWS. Both Hurricane Specialist and Severe Weather Meteorologists have found surface reports from home weather stations a valuable forecasting too].

Extensive tests of the Automatic Packet Reporting System at station W4EHW in Miami have demonstrated it will reliably display weather, 24 hours a day, from amateur radio stations between Key West and Palm Beach.

6. AMATEUR PACKET RADIO SYSTEM

Amateur radio is a noncommercial communications service of hobbyists and experimenters. The Federal Communications Commission grants privileges to these operators, better known as Hams, to design, build, buy and maintain various types of radio equipment for different methods of communications.

One such communication method is packet radio. Information is communicated by assembling data into packets and transferring that data over a radio communication network. An amateur radio station for packet consists of a computer, a terminal node controller, a radio and an antenna. A computer converts information to digital data format for transmission. The terminal node controller (TNC) is a modem that assembles and disassembles digital data into radio frequency packet format to link the computer to the radio. The radio transmits the packet data at assigned frequencies over an amateur communications network. Data can be transmitted to a central collection site from many locations and over a substantial distance.

One application of packet radio is the Automation Packet Report System (APRS). This system operates at the receiving radio station where a computer decodes the packet data and displays it graphically. APRS displays on a map the station call, global location, weather information and text messages from radios transmitting on the radio net.

Utilizing APRS, weather service offices can receive weather information in virtually real time. Weather data can be displayed on APRS maps from any packet radio station providing weather data for that site.

Amateur radio volunteers in the Miami area have operated station W4EHW at the National Hurricane Center since 1980. The station has two radios, one operating on the 2 meter band and the other on IO meters. The NHC station reliably receives home weather station data by amateur radios on the 2-meter band between Key West and Palm Beach. Also, the 10-meter band radio receives data from home amateur radio weather station from greater distances.

7. PHOTOVOLTAIC POWER

Photovoltaic (solar electric) modules offer a source of quiet, safe, standalone and pollution-free electrical power. Photovoltaic (PV) systems are capable of providing the electrical energy for lighting, motors, communications, homes, traffic devices, weather stations and other general electrical needs. Standalone PV systems do not require refueling and operate for long periods of time from the endless energy supplied by the sun, making them beneficial for remote sites or during disaster efforts.

The photovoltaic cells convert sunlight directly into electricity. The cells act as current generators producing from milliamps up to 4 amps or more of direct current, depending on cell size. The cells are packaged into modules to produce typically 6 or 12 volts modules, but some modules are configured to produce up to 120 volts.

Because PV modules only work during the day, most PV power systems contain batteries to store the energy produced during the day for use at night. PV modules are manufactured to output a certain amount of power in watts with output varying based on size of the module.

Each location on the earth has varying amounts of solar energy shining on that location. The amount of solar energy varies with the time of day and the season of the year. Therefore, a PV module will produce maximum rated output only a few hours per day as the sun rises and falls. In Miami where NHC is located, the yearly average for the number of hours per day of maximum or full sun is 5.1 hours at a tilt angle equal to its latitude.

8. SYSTEM DESIGN DESCRIPTION

To meet the required design criteria, it was determined that the weather station design would be composed of four major subsystems. The primary subsystem was a home weather station that measures weather conditions. The next subsystem was a terminal node controller to convert the weather data to packet radio data format for transmission. The next subsystem is an amateur radio transceiver to transmit the data from the weather station to the packet radio network. To complete the station, a photovoltaic power system was needed to supply electrical power for stand alone operation. The system diagram is shown in Figure 1.

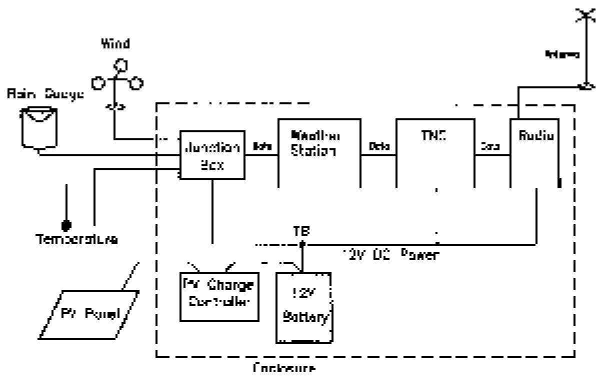

Fig. 1: Weather station components and configuration.

8.1 Component Specifications

The specifications and requirements for the different system components are summarized in the following paragraphs.

8.1.1 Weather Station

The weather station must measure a minimum of seven weather parameters as listed in Table 1. The sensors should be separate to allow mounting in any location. Minimum and maximum values will be recorded for a 24 hour period. Measurements will be made every second and averaged every five minutes

For this application, the Peet Bros.' ULTIMETER® 2000 weather station was selected. It had a serial data transfer mode for use with packet radio. Therefore, a computer is not required at the station.

8.1.2 Terminal Node Controller

The terminal node controller must interface with an amateur packet radio to convert computer serial data to radio frequency signals. The TNC needs to support ARPS, weather and global positioning system (GPS) data. The data needs to be transmitted at a minimum rate of 1200 baud and use AX.25 data protocol.

There should be separate HF and VHF/UHF radio ports capable of simultaneous operation. This provides the capability of using two different radio frequency bands, allowing local and long distance transmission. A DB-9 male connector is needed for connection to the radio and a 25 pin RS-232 connector for the weather station connection.

Table 1: REQUIRED DATA TO BE TRANSMITTED

Parameters	Visual Display	Incremental Units
Date and Time of Observation	mm/dd/yy hr:mn	NA
Barometric Pressure	Pressure: 93 /13 to 1067.0 mbar	0.1 mbar
Ambient Temperature	Temperature: -55°F to + 150°F	0.1°F
Sustained Wind Speed	highest 1 minute average over last 5 minutes	0.1 k mph
Gust Speed	highest wind gust over last 5 minutes	0.1 k mph
Wind direction	direction of the high gust over last 5 minutes	1.4° (1 part in 256)
Precipitation	00.0 inches	0.1 inch

8.1.3 Radio Transceiver

The radio must operate in the amateur radio band at frequencies of 140-148 MHZ. The radio should have automatic power off, battery saver features, repeater shift, repeater encode/decode tone generator and memory channels. External connections must be provided for speaker, microphone, power and an antenna. Output power should be selectable to at least 5 watts for F2 and F3 or G3E type emissions.

The antenna must be separate from the radio for external mounting and be compact for low wind resistance. The antenna should provide at least 3 db gain using a 50-ohm impedance connection.

8.1.4 PV Charge Controller

The charge controller must protect the battery from overcharging and over discharging, and maintain battery life. The charge controller must maximize the charge transfer from the photovoltaic module to the battery while minimizing cycling of the battery. The controller design should be solid state with reverse polarity protection. The controller should operate at voltages greater than the PV module open circuit voltage and currents greater than the maximum expected short-circuit current. Reverse current protection should be provided for the battery either in the controller or at the PV module.

The controller should operate at a maximum voltage of 22.1 volts and transfer currents up to 1.3 amps direct current. The low voltage disconnect of the controller should be set at 1 1.5 volts and the high voltage disconnect should be 14.2 volts or as recommended by the battery manufacturer. After low voltage disconnect, the load should reconnect at 13.0 volts.

8.1.5 Photovoltaic

As an indication of reliability in terms of electrical performance and the ability to withstand severe mechanical cycling and loading, the PV module must meet American Society of Testing Materials specification's document No ASTM-E 1036-85 entitled: "Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells," or equivalent tests.

The PV array should be sized to meet the electrical load requirements when operating with a plane-of-array irradiance of 800 W/m' and a PV module temperature of 55 degrees C. The electrical load is defined as the home weather station, TNC, and radio average current and voltage requirements when the system is operational. The PV should be mounted at an angle for maximum insolation during the worst month of the year for its location. The PV should be mounted at a tilt angle of latitude plus 10'.

8.1.6 Battery

The battery must be a sealed or gel-cell lead acid rechargeable type for portability and designed for deep cycle performance. The battery should typically operate in a daily shallow-cycle m(>de with the capacity to operate for a period of five days at a constant current of less than 0. I amp for a depth of discharge (DOD) greater than 70 percent. The battery should have a life greater then 350 cycles at 80 % DOD at the 20-hour rate.

8.2 Electrical Design

The electrical design must be in strict compliance with the National Electric Code (NEC). Article 690 of NEC specifically addresses safety standards for the installation of PV systems. This weather station includes: (1) disconnect circuit breaker switches to isolate the PV and battery from the rest of the system (2) a 2-amp fuse connected between the charger controller and the load terminal board, (3) U.L - listed wiring for outdoor use and for exposure to sunlight and water spray, and with sufficient voltage and amperage ratings, (4) water proof enclosure and anti-oxidation coating for electrical contacts, (5) surge arresters for lighting protection and (6) a ground connection.

The weather station system will use a nominal 12 volt DC power bus for all components. Reverse current protection should be provided for the battery by diodes either in the controller or at the PV module.

8.3 Mechanical Design

The overall size of the weather station system should permit transporting in a compact pick-up truck. The home weather station, TNC, radio, controller, battery and interconnects should be mounted in a rain and dust tight enclosure. The enclosure, PV module and weather sensors should be secured to a support structure.

The metal and electrical components' materials are chosen for corrosion resistance in the hot, humid, salt-air climate of Florida. Direct contact between dissimilar metals is avoided. Stainless steel fasteners are used for bolted connections. The support structure is two inch Unistrut members supporting the enclosure, PV module and weather sensors. The PV array, enclosure, support structure and sensors should be capable of withstanding 120 mph sustained winds. Suitable anchor attachments should be provided through the use of anchor bolts and sand bags. Provisions to ensure that the array is unobstructed around the perimeter should be made to ensure adequate air circulation and solar irradiance. The array is secured to the adjustable support structure at a tilt of 38 degrees from the horizontal for Miami.

9. PROTOTYPE WEATHER STATION OPERATION

The weather station has been in operation for a month and both FSEC and NWS are pleased with its performance. Local Harm and the NWS were able to receive and display our weather data at their radio stations using APRS.

This project required Peet Bros, the Florida APRS Users Group and Kantronics to modify their software and/or equipment to make this system configuration work. These recent changes allowed the weather station to operate as a beacon radio station capable of transmitting weather data without the use of an on site computer. This prototype system was designed and completed by the volunteer efforts and donations of the members of the team.

The weather station measured and collected local weather conditions for transmission every five minutes by the TNC. The APRS formatted weather data was transmitted across the packet radio net from station to station to NHC. This prototype unit uses a Yaesu handheld radio for only 2 meter operation. The completed system is shown in Figure 2. Any radio station using APRS software operating on 146.79 MHZ could receive the data and display it on a computer. Therefore, the weather data is available to anyone, not just the NWS or Hams.

Fig. 2: Complete weather station.

During testing, the system operated for five days powered only by the systems 13 amp/hour Hawker battery. From low voltage disconnect, the battery was recharged in 2 days with average solar irradiance. A 17-watt Siemens PV module was used to increase battery recharge time to provide greater flexibility in deployment of the 51 pound system. At the bottom of the Hoffman enclosure, a ground lug was mounted to provide electrical grounding of the system and the Lynics lighting protector on the coax connector for the radio.

The weather station consumed 25 watt/hours per day during continuous operation. There are three components that consume power in the weather station. The power requirements are defined in Table 2.

Table 2: LOAD ANALYSIS

Components	Current	Power
Weather Station	0.019 amps	0.228 w
Radio Modem (fNC)	0.026 amps	0.312 w
Radio Transmitter/standby	0.037 amps	0.444 w
Radio Transmitter/transmit	0.426 amps	5.12 w
Total Load/standby	0.063 amps	0.75 w
Total Load/transmit*	0.475 amps	5.65 w

* During transmission, the current jumps to 0.475 amps. The effect of this high current draw is minimal because the transmission duration is only 2 seconds for every five minute period.

10. CONCLUSION

The prototype photovoltaic powered amateur packet radio weather station reported in this paper performed as expected in initial testing. While a long term test will be conducted, the system utilizes well-established communication techniques and proven components. The home weather station monitor adequately measured the weather at its location. The weather data was reliably transmitted in near real time to the weather service by the amateur packet communications system. PV proved to be a viable source of electrical power for portable weather stations applications that require low power, long term use, and where support is difficult to provide. This prototype system represents a cost-effective application for collecting supplemental weather data for the National Weather Service.

11. ACKNOWLEDGMENTS

The weather station would not have been possible without the support and assistance of the following:.

Peet Bros' Company
Yaesu USA
Hutton Communications
Siemens Solar
Hawker Energy Products
Hoffman Engineering Company
TK Sales
Lynics International Corporation
Raybro Electric Supplies
Indiana River Amateur Radio Club Volunteers
Volunteers of W4ERW Amateur Radio Club
Drew Gillett Engineering
Florida Solar Energy Center

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