National Renewable Energy Laboratory
*Innovation for Our Energy Future*

*A national laboratory of the U.S. Department of Energy*
*Office of Energy Efficiency & Renewable Energy*

# Small Hybrid Systems and Applications Testing at NREL's Outdoor Test Facility

L. Roybal

*Presented at the 2004 DOE Solar Energy Technologies Program Review Meeting*
*October 25-28, 2004*
*Denver, Colorado*

***Conference Paper***
**NREL/CP-520-37078**
**January 2005**

NREL is operated by Midwest Research Institute • Battelle Contract No. DE-AC36-99-GO10337

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

# Small Hybrid Systems and Applications Testing at NREL's Outdoor Test Facility

L. Roybal
National Renewable Energy Laboratory (NREL)
National Center for Photovoltaics
1617 Cole Boulevard
Golden, CO 80401
lorenzo_roybal@nrel.gov

## ABSTRACT

The PV International Program at the National Renewable Energy Laboratory recently installed a small hybrid solar and wind energy system that could produce enough electricity to power a cabin or provide electricity in a remote village, without being connected to a utility grid. The solar system can provide 1,400 watts of power, and the wind turbine is rated at 900 watts when the wind is blowing at 28 miles per hour. The 48-volt system has eight batteries for storage. When the batteries are fully charged, the control system slows down the wind turbine so as not to overcharge the batteries. The turbine is mounted on a tilt-down, guyless, 30-foot tower that allows one person to easily lower and raise the machine for maintenance. A data acquisition system is being designed to monitor the individual outputs from the solar system and the wind system. The small hybrid system is housed in an insulated shed, the PV International Program's Test Building (ITB). The ITB contains electrical loads found in the average home, including a refrigerator, lights, heaters, air coolers, computers, and a radio.

## 1. Objectives

The generation of off-grid power for developing countries will meet the demand where basic power is not provided on an electric grid system. The ITB provides a controlled environment for the testing of equipment for use in developing countries to improve the quality of life for the residents.

## 2. Technical Approach

NREL's ITB (see Fig. 1), located at the Outdoor Test Facility, is the first off-grid small photovoltaic (PV) and wind hybrid system to be located at the Laboratory's Permanent Site. The ITB houses several experiments, including a multiple solar-lantern charging station, two ultraviolet (UV) water purification units, and the Ramakrishna Battery Charging Station.

## 3. Results and Accomplishments

The currently installed PV system can provide 2.8 kilowatts of power, although only 1.4 kilowatts is currently used for the charging of the building's battery storage system. A 30-amp battery charge-controller prevents overcharging of the eight deep-cycled, vented, lead-acid batteries in the 48-volt system. A 5.5-kilowatt sine-wave inverter provides AC power to the four 20-amp circuits. The remaining modules are assigned to power other systems in the building as needed. The entire 2.8-kilowatt array can be brought on line merely by flipping a switch. Using the custom-designed combiner box, individual modules can be assigned to a specific experiment, depending on the voltage required for the operation of each experiment. The combiner box is the most convenient way of, and offers the most flexibility in, assigning power where needed.

Fig. 1. NREL's International Test Building at the Outdoor Test Facility.

The currently installed wind turbine is a quiet and neighborhood-friendly 900-watt Whisper H40 manufactured by SouthWest Wind Power. It is mounted on an IDC guyless tilt-down tower that is 30 feet (10 meters) tall. The tower can be raised and lowered by one person, using the tilt-down crane provided by IDC, which attaches to the base plate of the tower. The crane is far more convenient than other methods of lowering a tower, and also includes the safety feature of not having to climb a tower. The tower crane disassembles for easy storage. The system is designed to handle up to a 1000-watt Whisper H80 turbine. This tower/turbine system is easy to assemble and maintain, as there is minimal maintenance on the tower itself.

The tower kit is mounted on a concrete base that is 4' x 4' in area x 7' in depth and consists of 5½ yards of concrete. Twelve separate j-bolts are threaded through the base plate and then installed into the wet concrete. The j-bolts extend

24 inches into the concrete, attaching to the rebar cage inside the concrete base. The base plate is attached to the hinge plate using a 1¼-inch-diameter stainless-steel hinge pin, which allows the tower to tilt down to ground level for easy maintenance of the turbine. The mounting of various monitoring devices, i.e., anemometer, wind vane, even a small solar module, may be mounted up near the top of the tower if total weight does not exceed ten pounds. IDC's tower includes an Up-Tower J-Box, which allows a very convenient disconnect for maintenance and/or replacement of the turbine. It can also provide strain relief to keep wire strain from the turbine. Because the tower is a hollow, extruded-aluminum tube weighing about 200 pounds, all wiring is protected from the elements and vermin.

An EZ-Wire 2 battery charge-controller prevents overcharging of the eight batteries in the 48-V system. The batteries are kept fully charged using both the wind system and the PV system. By adding the wind system, the batteries can now charge during the nighttime hours and on dark cloudy days. By adding the 900-watt turbine to the PV system, we have been able to add several other pieces of equipment—a water cooler, another computer, and two desk lamps can now be operated 24 hours a day.

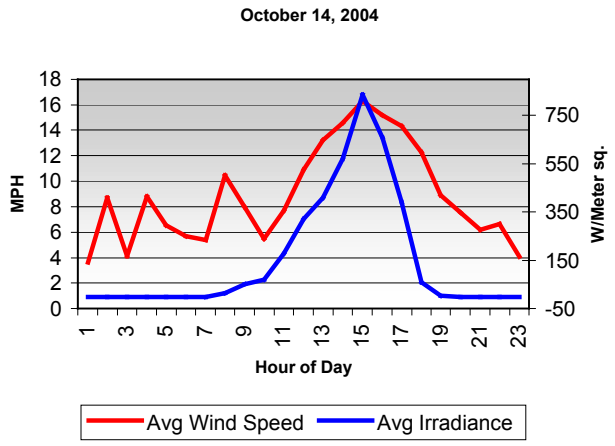


Fig. 2. Solar and wind comparison for October 14, 2004.

The batteries are manufactured by Trojan, model L-16, and provide a 390-amp-hour storage capacity. Electrical loads in the ITB include a water cooler, refrigerator, lights, diode bulbs, desk lamps, air coolers, computers, overhead house lights, heaters, a radio, and data acquisition systems. The loads are all 120-V, 60-Hz AC.

A solar-lantern charging station is also available for testing different types of lanterns, including a multiple solar-lantern charging station. Lower-voltage modules are used in these types of systems and can be mounted outdoors.

A Ramakrishna Battery-Charging Station is being tested at the ITB. The battery-charging station is designed to charge multiple batteries, up to ten, using a minimal number of PV modules. At this time, three modules are dedicated to this experiment. The three 12-volt, 120-watt modules charge the system's one 12-volt, 220-amp-hour battery. This, in turn, charges one to ten batteries. Ten battery charge-controllers are wired in parallel to control the output. Due to the reverse-current diodes installed in the output stage, a 1-volt drop occurs, keeping the batteries from reaching their full state of charge.

Two UV water purification systems are powered by one 12-volt, 90-amp-hour battery and one 120-watt module. A 12-volt, 5-amp water pump operates the Water Fixer system. The Water Works system is gravity fed. Both systems use a 12-volt, 35-watt DC UV lamp. The water systems are cycled on a 7-hour on, 1-hour off, and 7-day cycle to test the UV lamps. The lamps are rated for 10,000 hours of operation, so the cycling of the systems allows the lamps to be tested to failure more rapidly than using an "always on" schedule. When the UV lamp loses its intensity, the water may not be purified as specified. Because of these tests, a safety water valve has been installed in the new Water Works system, which will shut off the water input valve until a new lamp is installed.

Campbell Scientific CR10X data acquisition systems are used to monitor and record data from the multiple experimental systems. The live data can be viewed by the public at the ITB's Web site, and are also stored for further analysis. Data points currently include indoor and outdoor temperature, wind speed, wind direction, and plane-of-array solar irradiance, which is at a 23-degree tilt (5-12 pitch). Future data points will include percent of battery charge provided by the PV and/or wind system. A 45-degree solar irradiance latitude-tilt measurement will compare the irradiance losses during the winter months.

Plans are currently being drawn up to add a hot-water heating system to the ITB to provide reliable and efficient heating for the winter months. The data acquisition system will document the greater efficiency of the hot-water heat vs. electrical heat, which is presently used.

## 4. Conclusions

NREL's small hybrid system demonstrates the real-world application of PV and wind energy, working together where conventional grid power is not available or desirable.

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



**PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.**

| 1. REPORT DATE *(DD-MM-YYYY)* | 2. REPORT TYPE | 3. DATES COVERED *(From - To)* |
|---|---|---|
| January 2005 | Conference Paper | |

**4. TITLE AND SUBTITLE**
**Small Hybrid Systems and Applications Testing at NREL's Outdoor Test Facility**

**5a. CONTRACT NUMBER**
DE-AC36-99-GO10337

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
L. Roybal

**5d. PROJECT NUMBER**
NREL/CFP-520-37078

**5e. TASK NUMBER**
PVP49001

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

**8. PERFORMING ORGANIZATION REPORT NUMBER**
NREL/CFP-520-37078

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

**10. SPONSOR/MONITOR'S ACRONYM(S)**
NREL

**11. SPONSORING/MONITORING AGENCY REPORT NUMBER**

**12. DISTRIBUTION AVAILABILITY STATEMENT**
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT** *(Maximum 200 Words)*

The PV International Program at the National Renewable Energy Laboratory recently installed a small hybrid solar and wind energy system that could produce enough electricity to power a cabin or provide electricity in a remote village, without being connected to a utility grid. The solar system can provide 1,400 watts of power, and the wind turbine is rated at 900 watts when the wind is blowing at 28 miles per hour. The 48-volt system has eight batteries for storage. When the batteries are fully charged, the control system slows down the wind turbine so as not to overcharge the batteries. The turbine is mounted on a tilt-down, guyless, 30-foot tower that allows one person to easily lower and raise the machine for maintenance. A data acquisition system is being designed to monitor the individual outputs from the solar system and the wind system. The small hybrid system is housed in an insulated shed, the PV International Program's Test Building (ITB). The ITB contains electrical loads found in the average home, including a refrigerator, lights, heaters, air coolers, computers, and a radio.

**15. SUBJECT TERMS**
PV; small hybrid system; solar system; wind energy system; data acquisition system; ultraviolet (UV);

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | 19b. TELEPHONE NUMBER (*Include area code*) |
| Unclassified | Unclassified | Unclassified | UL | | |