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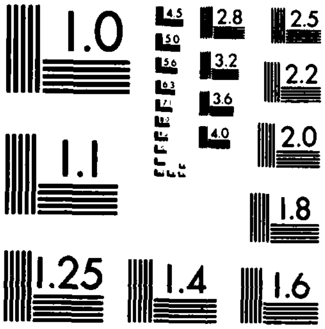

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US Army Corps
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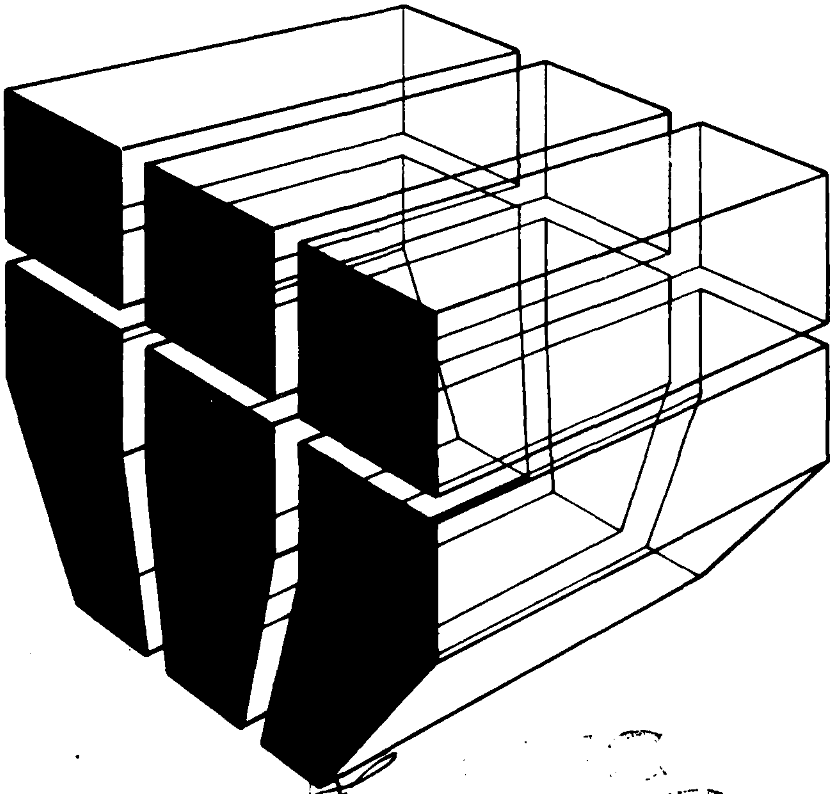
Construction Engineering
Research Laboratory

TECHNICAL REPORT E-195
May 1984

A PHOTOVOLTAIC POWER SYSTEM FOR THE HOLMAN GUEST HOUSE, FORT HUACHUCA, AZ

by
D. M. Joncich



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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report documents the specification, design, installation, and acceptance of a 5-kilowatt-peak, grid-connected, photovoltaic power system for the Holman Guest House at Fort Huachuca, AZ. This system, designed and installed at a cost of $112,000, was funded by the Department of Energy's Federal Photovoltaic Utilization Program.

The system operates in parallel with the local utility grid without battery storage. The photovoltaic (PV) array, consisting of 196 roof-mounted panels, generates direct

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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)* current at about 210 V. The array output is converted to alternating current by a three-phase, line-commutated inverter developed specifically for the application. The inverter output, estimated at about 11,000 kWh per year, meets a portion of the Guest House's electrical demands.

Tests performed at the time of the system's acceptance have demonstrated its ability to deliver the rated power output. The U.S. Army Construction Engineering Research Laboratory is now conducting a 1-year evaluation to determine the system's long-term performance and to learn more about the feasibility of applying grid-connected PV systems to fixed military facilities.

FOREWORD

This work was performed with funds provided by the U.S. Department of Energy. This report was prepared by the Energy Systems Division (ES) of the U.S. Army Construction Engineering Research Laboratory (CERL). Mr. S. Cerami, Mobility Equipment Research and Development Command, DRDME-EAC, was the project Technical Monitor; the work was coordinated with the Office of the Chief of Engineers (OCE) through Mr. E. Zulkofske, DAEN-ECE-E.

Appreciation is expressed to Messrs. A. Lawson, E. Sequeira, and C. Savage of the Jet Propulsion Laboratory; Mr. K. Van Karsen, Fort Huachuca; Dr. P. Russell of Arizona State University; and Drs. A. Averbuch and D. Johnson, CERL, for the support they provided to this project. Mr. R. G. Donaghy is Chief of CERL-ES.

COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

A PHOTOVOLTAIC POWER SYSTEM FOR THE HOLMAN GUEST HOUSE, FORT HUACHUCA, AZ

1 INTRODUCTION

Background

The Department of Energy Act of 1978 mandated that the U.S. Department of Energy (DOE) work cooperatively with other Federal agencies to implement a program to accelerate the procurement and installation of photovoltaic (PV) systems at Federal facilities. Public Law 95-619 authorized the Federal Photovoltaic Utilization Program (FPUP) to provide for the acquisition of PV solar electric systems at an annual level great enough to encourage development of low-cost production techniques. Other objectives of this program were to:

1. Accelerate the growth of a commercially viable and competitive industry which would make PV systems available to the general public.

2. Reduce fossil fuel consumption and costs for the Federal government.

3. Stimulate the general use, within the Federal government, of methods for minimizing PV system life-cycle costs.

4. Develop performance data on PV technology.

To achieve these objectives, FPUP supported PV applications with significant market potential in the private sector, in foreign countries, and within Federal organizations. FPUP was implemented in four funding cycles, and included demonstrations ranging from small, remote systems to larger grid-connected ones. The project described in this report was funded as part of Cycle III. It provided the Army, through the Mobility Equipment Research and Development Command, its first opportunity to apply a photovoltaic power system to a permanent facility.

Purpose

The purpose of this report is to document the design, installation, and acceptance testing of a grid-connected photovoltaic power system on the Holman Guest House at Fort Huachuca, AZ.

Approach

An installation and a building were selected for the demonstration PV system. Specifications for the system design and installation were developed, and the system was procured.

Acceptance testing of the installed system was performed and tasks for determining the system's long-term performance and reliability were defined.

Scope

This report discusses only the design and installation of the PV system and the tasks necessary to establish its long-term performance and reliability. A separate report will summarize system performance and analyze the economic feasibility of using PV on military fixed facilities.

2 SYSTEM DEVELOPMENT

Site Selection

Obtaining the greatest PV system output required a demonstration site in a sunny climate. Therefore, Army installations in the Southwest United States were surveyed, and Fort Huachuca, AZ, was chosen as an ideal candidate location. Personnel at the installation were contacted and agreed to assist with the project.

At Fort Huachuca, the inventory of buildings was surveyed, and criteria were developed for identifying which facility would ultimately house the system. These criteria included requirements that the project be located in a well-lit, high-visibility area on a building of proper orientation with a reasonably flat roof. The Holman Guest House was subsequently selected as the system location. The Guest House is a one-story, motel-like structure having a nominal roof area of 12,000 sq ft available for mounting the PV array. The roof contains a ridge which runs east-west along its long dimension; the pitch along the other axis is 1/2 in. per foot. The building is serviced by 100-amp 120/208 three-phase electrical mains, and is separately metered. Recording ammeter readings taken on-site indicated that the baseline electrical consumption of the facility at that time was about 9 kW.

Specifications

Design and installation specifications were prepared after evaluating bid packages from several other military photovoltaic projects. The project agreement with DOE required that the system use flat-plate, nonconcentrating, silicon PV panels, and that it be grid-connected without battery storage. Preliminary cost analysis indicated that, with the funds available to the project, system output would be about 5 kilowatts-peak (kWp).

Two major procurement methods were available: (1) formal advertisement via an Invitation for Bid (IFB), or (2) negotiation via a Request for Proposal (RFP). An IFB was chosen because it was the most direct procurement method and because it would be preferable to an RFP if a significant number of PV systems were to be installed on military facilities in the future. A draft IFB was produced which described the functional requirements for a 5-kWp, grid-connected system at the Guest House. However, the contractor was made responsible for supplying all parts and labor for the detailed system design, procurement, installation, and verification of proper operation.

The draft IFB was sent to the Solar Energy and Semiconductor Materials Section of the FPUP working group at the Jet Propulsion Laboratory (JPL) for review. Their comments were incorporated into the final version of the system solicitation notice, the technical portion of which is provided in the appendix.

The specification is divided into five major sections: project description, system design, system installation, system acceptance, and system operation and maintenance (O&M) documentation. The contractor is provided with site-specific information to assist in the bid preparation, including a description of the Guest House, a summary of local climate conditions, and several references to applicable documents.

The system's major components are the photovoltaic array, the array support structure, and the power conditioning (PC) equipment. The array is to consist of flat-plate, silicon-based PV panels, and is to be mounted on the roof of the Guest House in a frame designed for a 20-year life. The PC system must be sized to match the capacity of the array, and is to be capable of converting the array DC output to 60 Hz, 120/208 three-phase AC in phase with the existing utility grid. The system is further specified as being a fixed-voltage system (not a maximum power tracker), and its operation is to be totally automatic.

The requirement for on-site instrumentation has been minimized to hold down costs. Provisions are made only to facilitate the servicing and overall monitoring of the installated system. The PV array, support structure, and PC equipment are also to be protected from lightning damage.

Final acceptance will be based on a verification that the installed system is performing as designed and is in compliance with all specification provisions. The contractor is responsible for demonstrating that the system output, after correction to standard operating conditions, is 5 kWp. In addition, 10 days of continuous measurements are required to substantiate that the automatic startup and shutdown circuitry within the PC equipment is operational. Once accepted by the government, the system is to be under warranty for 2 years.

The final section of the specification deals with O&M documentation. While the contractor is not required to maintain the system after it has been installed, he/she is responsible for training on-site personnel and for providing a system operating manual. This document is to contain schematics, a parts list, a description of operating procedures, and a suggested system maintenance schedule. The contractor must also post framed instructions, including schematics, in the mechanical room of the Guest House.

The IFB was formally advertised in the *Commerce Business Daily* in August 1981. Seven firms responded, with bids ranging from $112,317 to $224,137. The contract was awarded in September 1981 to the low bidder — Monegon, Ltd., of Gaithersburg, MD.

Design and Installation

Design of the PV system was completed in early 1982, and installation was essentially completed in October 1982. The system contains a photovoltaic array mounted on the roof in an aluminum framework secured at a fixed tilt of 30 degrees from the horizontal (see Figure 1). The array DC output (about 210 V) is converted to alternating current by an inverter located in a protected area next to the building. The inverter output powers a portion of the house's electrical loads.

The PV system feeds power into the utility grid if PV electricity production exceeds the demand. Similarly, the grid provides the power during periods of excess demand and at night. System operation is totally automatic.

The array consists of 196 Solarex Corporation Model 5300 EG panels. Under full sunlight, each panel produces about 31.5 W at 15 V DC. The array is wired so that there are 14 parallel strings of 14 panels connected in series. Each string is provided with a blocking diode to minimize the degradation of the array performance in case one of the strings fails. Each panel also has a bypass diode, which allows a single string to operate, even if a panel in that string fails.

The panels are constructed from a sheet of tempered glass to which the solar cells are bonded. The cells are wafers cut from 4-in.-diameter single crystals of silicon. There are 38 cells per panel, connected in series. The base material is p-type, boron-doped silicon. The cells have electrical contacts silk-screened on the front, and are encapsulated in ultraviolet-stabilized silicon rubber. The glass-cell assembly is enclosed in an extruded aluminum frame.

The system inverter converts the power produced by the PV array into 208-V, three-phase AC. The inverter is a solid-state, line-commutated device designed specifically for this application. Using the AC utility lines to determine the voltage waveform and frequency, the inverter produces a high-quality, 12-pulse output at an efficiency of about 94 percent. It automatically disconnects and shuts down whenever the grid power is interrupted.

The site instrumentation consists of three totalizing AC kWh meters. The first records the total PV system power output. The second measures the total power provided by the utility grid to the Guest House; it has been detinted so that it will not decrement when energy from the PV system is fed back into the grid. The third meter records the Guest House's total power consumption. A terminal strip has also been installed at ground level to facilitate measurements of the PV system's DC and AC voltages and currents.

A surge arrestor protects the electronic circuitry from lightning. This device employs a silicon oxide junction which is normally insulating, but which ionizes in the presence of a high voltage. When ionized, this junction protects the components downstream. Lightning rods were not considered necessary, because nearby buildings and lamp posts are higher than the Guest House.

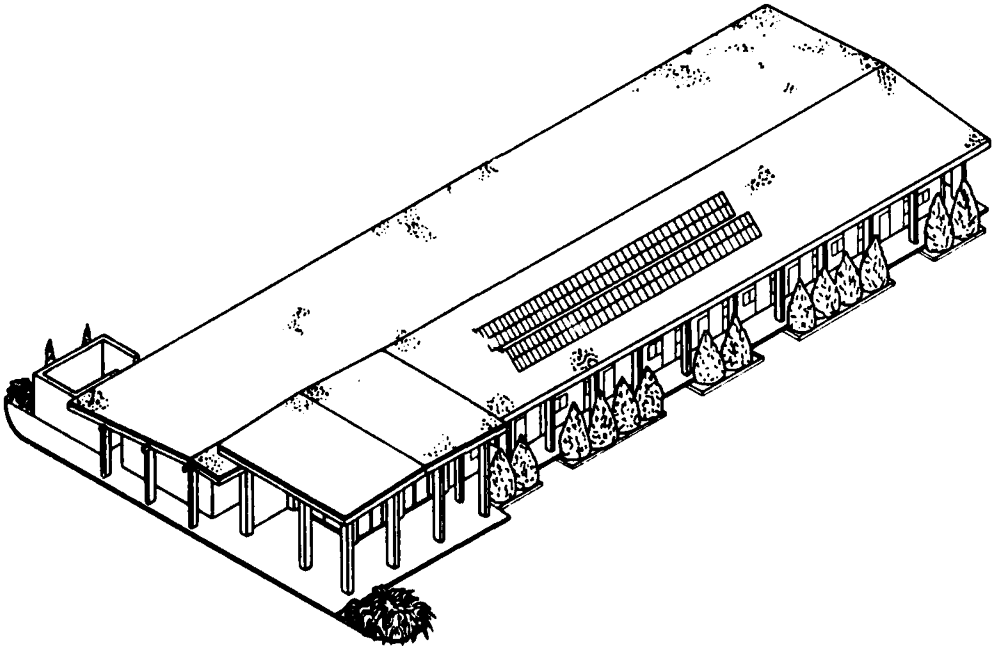


Figure 1. Photovoltaic power system, Fort Huachuca, AZ.

3 TEST AND EVALUATION

Acceptance Testing

Acceptance of the photovoltaic system at Fort Huachuca was performed in two phases. In the first phase, the contractor submitted all relevant project documentation; in the second phase, Fort Huachuca Directorate of Engineering and Housing (DEH) staff inspected the site to substantiate that the system, as installed, met the project specifications. System operators were also trained at this time.

The project documentation included the following:

1. System as-built drawings. This packet consisted of 19 sheets describing the system's electrical, mechanical, and structural details. Figure 2 shows an electrical single-line drawing.

2. Laboratory test results for the system inverter. These data were used primarily to verify that the inverter had met the efficiency, power factor, and harmonic distortion specifications. The unit was found to be acceptable in all these areas.

3. On-site measurements. Before acceptance testing was begun, the contractor had taken continuous measurements of the system's AC and DC voltages and currents and of the solar radiation incident on the PV array. These data were submitted to demonstrate that the installed system was delivering its rated power output and that the automatic startup and shutdown circuitry was operational.

Calculations based on these data indicated that after corrections to standard conditions, the PV system output was 5.2 kW. This value exceeded the 5.0 kW called for by the system specifications.

Figure 3 gives an overview of system operations during "typical" sunny conditions, as provided by data taken on a clear day. The solar radiation peaked around noon at a value between 950 and 1000 W/m^2. Because the area of the array is about 100 m^2, this corresponds to a solar input to the system on the order of 100 kW. The system AC output tracked the solar input, producing a maximum power of about 5 kW at noon. The overall system efficiency is therefore roughly 5 percent.

4. System O&M documentation. An O&M manual for the system was submitted. The contents of the manual included the items described in the *Specifications* section.

During the second phase of system acceptance, DEH personnel developed a list of construction deficiencies which they recommended be corrected before the system was accepted. Most of these items were minor and were addressed by the contractor in December 1982. The PV system at the Guest House was formally accepted by the government in February 1983. However, the system had been functionally operational since October 1982.

Monitoring

Following system acceptance, data were needed to document the system's first-year performance and reliability and to provide assistance to DEH staff responsible for system operation and maintenance. To obtain these data, a contract to perform the following tasks was awarded to Arizona State University in January 1983:

1. Monitoring of system performance and reliability:

    a. Tabulation of monthly values for solar energy available to PV array.

    b. Monthly loggings of the electrical energy delivered to the Guest House by the PV system and by the utility grid.

    c. Estimation of the system downtime, including the frequency and duration of utility grid outages during the data collection period.

    d. A record of the PV system operation and maintenance requirements in terms of time and dollars spent for repair.

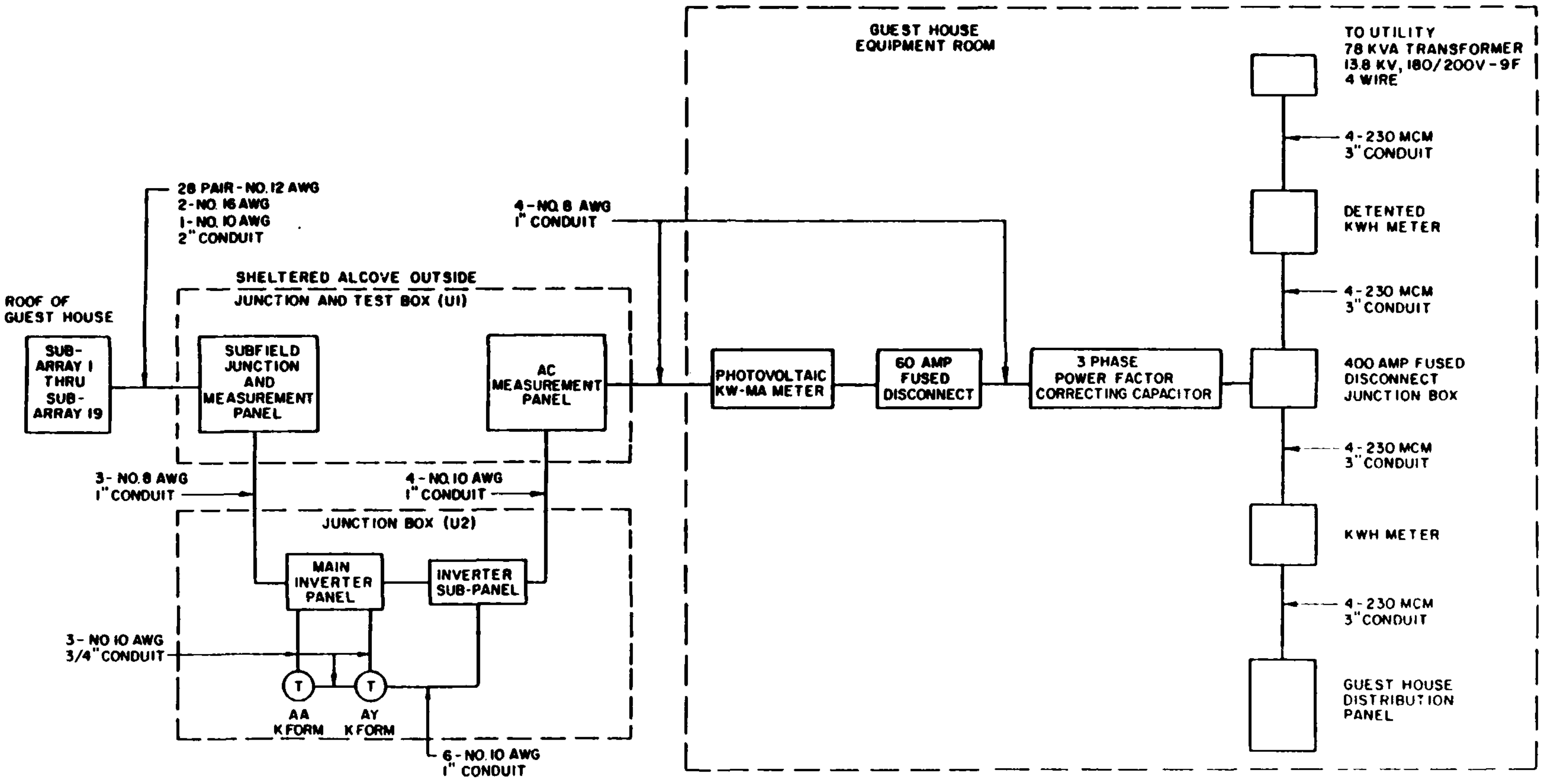
    e. Determination of the PV system's average monthly and yearly efficiency.

    f. Calculation of the system's monthly and yearly capacity factor.

    g. Tabulation of the monthly and yearly dollar savings corresponding to the energy the system delivers to the Guest House.

2. Assistance with system operation and maintenance:

    a. Development of a system logsheet to assist DEH personnel in collecting the required data.



NOTE:

1. COMMON GROUND EXISTING THROUGHOUT SYSTEM.

Figure 2. PV system schematic.

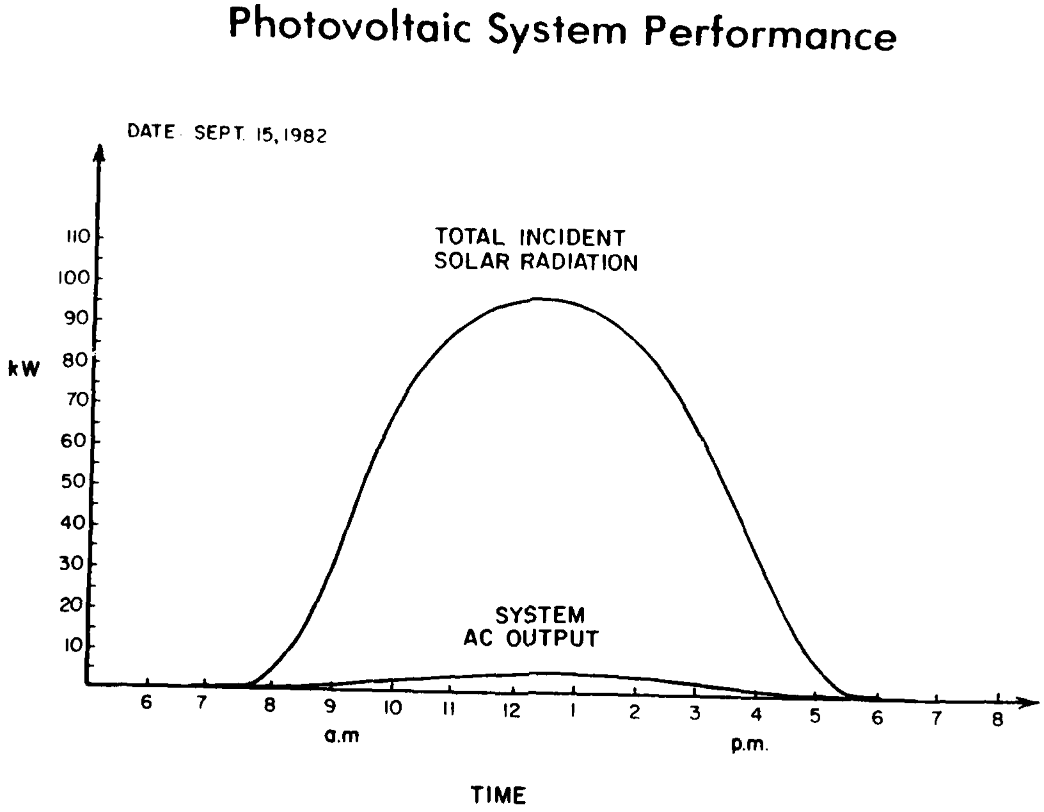


Figure 3. PV system "sunny day" performance.

b. Recommendations regarding type and frequency of routine system maintenance.

c. Advisory services to DEH staff in diagnosing system malfunctions.

d. Development of troubleshooting procedures for the use of DEH staff in diagnosing system malfunctions.

e. Recommendations regarding the number of PV system spare parts required.

f. Summary of any recurring problems in system operation and maintenance.

The results of Arizona State's study will be issued as a separate report.

Analysis

A detailed analysis of system performance, reliability, and economic feasibility would be premature at this time. However, in general, the system at Fort Huachuca has been working reliably so far, and on several occasions it has provided electrical power in excess of demand.

As part of the acceptance testing documentation, the contractor supplied a theoretical analysis of system output throughout the year. These estimates (Table 1) include monthly values for the site isolation, the average daily electrical energy supplied by the system, and monthly totals for the electrical energy delivered. Table 1 shows that over 1 year, the system can deliver an estimated 11,000 kWh of electricity either to the house or to the utility grid.

A complete understanding of the economic feasibility of this project would require a detailed life-cycle economic analysis. Strictly speaking, this analysis would include a consideration of all system capital and O&M costs, the discount rate, the current price of electricty at the site, and an assumed escalation rate for future electrical prices. Due to the uncertainty of many of these factors, only a qualitative estimate of system cost-effectiveness is provided here, and is calculated simply by dividing the system first cost by its projected lifetime electrical output.

The cost of the system was \$112,000. If the system produces 11,000 kWh per year for 20 years, the electricity would cost roughly \$.50/kWh. This is still substantially higher than the retail price of electricity from privately owned utilities, which now averages \$.06/kWh nationwide.

However, many observers believe that PV cell costs will decrease significantly in the near future. As the price of PV equipment decreases, and the cost of conventionally produced electricity rises, the costs may eventually be comparable.

4 SUMMARY AND CONCLUSIONS

A photovoltaic system for supplying power to the Holman Guest House at Fort Huachuca, AZ, was successfully designed and tested. The system contains a photovoltaic array mounted on the house's roof. The array's DC output is converted to AC by an inverter, whose output (about 11,000 kWh per year) provides part of the power used for the facility's operations. Upon completion, the system was tested and found to meet the project specifications; however, at this time, the costs of this type of energy production are much greater than for conventional methods.

On the basis of the research done for this investigation, the following conclusions are drawn

1. The military can successfully procure PV systems via an Invitation for Bid (IFB); the system at Fort Huachuca, as installed, met all the project specifications and has been performing reliably since going on line in October 1982.

2. With the predicted reductions in component costs and projected increases in electric rates, photovoltaic systems may eventually be competitive with the utilities.

Table 1

Fort Huachuca Photovoltaic System
Theoretical Calculations

Month	Insolation Sun-Hrs (kW/m^2)	Avg. Daily Energy (kWh)	Monthly Energy (kWh)
Jan	3.46	18.45	572
Feb	4.51	23.90	669.
Mar	5.88	30.81	955.
Apr	7.45	38.32	1150
May	8.42	42.47	1316.
Jun	8.60	42.48	1274
Jul	7.38	36.04	1117.
Aug	6.88	33.82	1049.
Sep	6.24	30.95	928.
Oct	5.05	25.69	796.
Nov	3.81	19.93	598.
Dec	3.14	16.68	517.
TOTAL			10941.

APPENDIX:
PV SYSTEM STATEMENT OF WORK

1. Project Description

1.1 Requirement:

A grid-connected photovoltaic (PV) power system with an output of 5 kWp shall be installed and placed into operation at the Holman Guest House located at Ft. Huachuca, AZ. This system shall consist of the following components:

a. An array of flat-plate, non-concentrating, silicon PV cells mounted on a supporting structure to be located on the roof of the Guest House.

b. All power conditioning (PC) equipment required to interface the PV array with the 120/208V three-phase power grid which exists on site.

c. Sufficient instrumentation to permit the operation and maintenance of the system once installed.

Means for storage of electrical energy is *not* required or permitted.

1.2 Scope:

The Contractor shall be responsible for all aspects of the PV system design, procurement, installation, instrumentation, and evaluation for satisfactory operation as described herein and shall supply all labor, materials, supervision and support required to meet the requirements of this Statement of Work. In addition, the Contractor shall provide the Government with complete system documentation, and shall train on-site personnel in all phases of the system operation and maintenance. The Government will provide no materials or labor for this project.

1.3 Applicable Documents:

a. JPL Document 5260-5, Revision A, *Solar Cell Module Design and Test Specification*, 30 Apr 81.

b. JPL Document 5101-21, Revision A, *Rejection Criteria for JPL LSSA Modules,* 28 Jun 77.

c. National Electrical Code, 1981.

d. JPL Document 5101-164, *Interim Standard for Safety: Flat-Plate Photovoltaic Modules and Panels,* Volume 1, 20 Feb 81.

e. Engineer Manual EM 385-1-1, *Safety and Health Requirements Manual,* USACE, April 1981.

1.4 Site Description:

The Holman Guest House is a one-story, motel-like structure having a nominal roof area of 12,000 ft^2 available for array mounting. The roof contains a ridge which runs east-west along its long dimension; the pitch along the other axis is 1/2 in. per foot. The building is currently serviced by 100-amp 120/208V three-phase mains and is separately metered. Recording ammeter readings taken on-site indicate the baseline electrical consumption of the facility to be approximately 9 kW. Building drawings containing more detailed information with regard to the structure's siting and construction are given in Appendix.

1.5 Design Conditions:

This information is provided to assist the Contractor in his bid. The Contractor is responsible for updating, supplementing, or amending these figures as required to assure that the most accurate data is used for the system.

Site coordinates:	31°3'N, 110°2'W
Elevation:	4664 feet above sea level
Winter design temperature:	24°F (ASHRAE 99% DB)
Summer design temperature:	95°F (ASHRAE 1% DB)
Maximum temperature:	110°F
Isokeraunic level:	25 thunderstorms/year, average
Average precipitation:	16 inches/year
Windload:	85 mph, maximum
Snow depth:	Minimal

Average Daily Insolation (kWh/m^2/day)

Surface Tilt
(Degrees from Horizontal)

Month	0	20	30	40
JAN	3.5	4.8	5.3	5.6
FEB	4.7	5.9	6.3	6.5
MAR	6.0	6.9	7.1	7.1
APR	7.4	7.8	7.7	7.4
MAY	8.2	8.0	7.6	7.0
JUN	8.5	8.0	7.4	6.8
JUL	7.7	7.4	7.0	6.4
AUG	7.2	7.3	7.1	6.7
SEP	6.3	6.9	6.9	6.8
OCT	5.2	6.3	6.6	6.8
NOV	3.9	5.2	5.7	6.0
DEC	3.3	4.5	5.0	5.3
YRTOT	2187	2400	2419	2381

2. System Design

2.1 Photovoltaic Array:

Individual PV modules shall meet the requirements of *JPL Document 5260-5, Revision A*. Each module shall have parallel bypass diodes installed to prevent damage from reverse biasing and cell interconnections shall be sufficiently redundant to preclude a complete module failure if one cell fails. The PV array shall be designed so that individual modules are interchangeable and may be removed for maintenance or repair without adversely affecting the operation of the remainder of the array. Guidelines for module selection are given in *JPL Document 5101-21, Revision A*.

2.2 Array Support Structure:

The photovoltaic modules shall be mounted on rigid, stationary frames to be located on the roof of the Guest House. These frames shall be designed for a 20 year life, and the array tilt angle and orientation shall be fixed to maximize the array annual power output. The design of the support structure shall provide for module and roof maintenance and repairs, and the array spacing shall be adjusted so the PV panels do not shade one another. The number of roof penetrations required by the array installation shall be minimized and the support structure must not impair the structural integrity of the roof. If the array support is metal, low maintenance, corrosion-resistant materials shall be used, and dissimilar metals isolated from one another in all cases. The array support structure shall not trap water and shall be designed to withstand the local 20 year maximum wind conditions without damage.

2.3 Power Conditioning Equipment:

The PC system shall be sized to match the capacity of the PV array, and shall be capable of converting the array DC output to 60 Hz, 120/208V three-phase 4-wire AC in phase with the existing utility power system. The PC equipment shall be designed such that when the net PV system output is insufficient to meet the needs of the guest house, the utility power system supplies the remainder of the required power. When the array output is in excess of the needs of the guest house, surplus power shall be fed back to the utility power system. Automatic start-up and shut-down circuitry shall be incorporated within the PC system to ensure that the above requirements are met; under no conditions shall the utility system supply power to the PV array. The PC equipment shall contain a provision for manual system start-up and shut-down. In addition, for safety reasons, the entire PV system must disconnect automatically from the utility system whenever a utility system outage occurs. The PV system shall be a fixed voltage system, not a maximum power tracker. The PC system shall be located in the Mechanical Room of the Guest House and shall satisfy the following requirements:

Efficiency:	85% from 50-100% full load
Harmonic distortion:	Less than 15%
Power factor:	.85 lagging to .85 leading
Protection:	Overload, short circuit, brownout

All system wiring shall be in accordance with the National Electric Code. Particular attention shall be given to the grounding of the system array, support structure, and power conditioning equipment. In addition, ground fault circuitry shall be included to terminate the system operation in the event that a current in excess of 250 mA DC exists in the system ground leg.

2.4 Lightning Protection:

The PV array, support structure, and PC equipment shall contain a lightning protection system which will preclude damage to the PV system and Guest House. Guidelines for accomplishing this task are given in Appendix.

2.5 Instrumentation:

The PV system instrumentation package, provided to facilitate the servicing and long-term monitoring of the installed system, shall consist of the following elements:

a. A solar pyranometer for measuring the total instantaneous hemispherical radiation (beam + diffuse) in the plane of the PV array. The nominal output of this instrument shall be 100 mV/kW-m^2, and its accuracy is to be ±5% of full-scale output. Wiring from this device shall be routed back to the Guest House Mechanical Room. (Suggested model: Dodge Products SS-100 or equivalent.)

b. A terminal strip containing discrete sets of terminals which allow the measurement of the DC output current of each branch circuit of the PV array, the total DC current delivered by the array to the inverter, the array (fixed) DC voltage, the inverter AC output current for each of its three phases, the inverter AC voltage output, and the DC voltage output of the solar pyranometer. Each set of terminals is to be clearly labeled with a legend describing the quantity being measured and its corresponding full-scale output.

c. Three totalizing AC kWh meters. These instruments shall be designed for three-phase, 120/208V service and must measure true power to 1%. (Suggested model GE V-64 or equivalent.) One meter shall be installed to record the total PV system power output. A second shall measure the total power supplied by the utility grid to the Guest House; this meter shall be detented so that it will not decrement in the event that energy from the PV system in excess of the Guest House demand is put back into the utility power system. The third meter currently exists on-site and shall measure the total power consumption of the Guest House.

2.6 Safety:

It is essential that the PV system not impose a safety hazard on any of the building occupants or operators. PV system safety requirements given in *JPL Document 5101-164* shall be met. In addition, construction and operational requirements of *EM 385-1-1* shall be met.

2.7 Design Information Submittals:

Upon completion of the PV system final design, the Contractor shall submit to the Contracting Officer three (3) complete sets of the system documentation, consisting of component specifications and performance data and of all system drawings and installation details.

3. System Installation

3.1 General:

The Contractor is responsible for all aspects of the procurement and installation of the PV system, including materials acquisition, site preparation, system fabrication and assembly, connection to the existing utility, and system check-out and start-up.

3.2 Photovoltaic Module Acceptance:

Special attention must be paid to the performance, quality control, and delivery time of the PV panels. The Contractor shall notify the Contracting Officer two (2) weeks prior to the time of the module procurement. Because the PV array is such a critical element of the PV system, the Government shall be permitted, at its discretion, to send representatives to witness the testing of the modules to be installed in the final system. At that time, the Contractor shall demonstrate that the modules are being evaluated in accordance with the *JPL Document 5260-5, Revision A*. All modules shall be numbered, factory tested for power output, and power curves for each module recorded.

3.3 Construction Clearance:

The Government will identify a Point-of-Contact (POC) in the Directorate of Facilities Engineering (FE) at Fort Huachuca for liaison during the course of the Contract. Prior to commencing with on-site construction, the Contractor shall obtain the proper clearance from the POC at Fort Huachuca. At that time, the Contracting Officer shall also be notified that the system installation is to begin.

3.4 Scheduled Power Outages:

The Contractor shall notify the FE POC at least two (2) working days prior to any power outage required by the PV system installation. Each power outage should last no longer than four (4) hours, if possible.

3.5 Attractive Hazard:

The Contractor shall take special precautions to avoid endangering Fort Huachuca personnel or property during the course of the PV system installation and testing. Upon completion of construction, the Contractor shall remove all debris related to the system construction and installation.

4. Evaluation and Acceptance

4.1 Test Procedures:

The Contractor shall submit to the Contracting Officer a written description of all operational tests to be used to demonstrate satisfactory system performance, including, but not limited to, those described below. The contractor shall perform the tests on the completed PV system and document the test results with a written narrative and supporting data. All test schedules shall be coordinated with the Contracting Officer and the FE POC. Upon completion of the PV system installation and testing, the Contractor shall also prepare a brief report summarizing the system design, procurement and installation costs and describing any problems encountered in placing the PV system into operation. The format for this report is given in Appendix.

4.2 PV System Output:

The Contractor shall operate the PV system and take continuous readings of the PV system voltages and currents (AC and DC) and of the solar insolation for a period of ten (10) consecutive days. The following documentation of the operational test shall be provided to the Contracting Officer:

a. A comparison, complete with backup calculations, of the theoretical PV array output to its measured output.

b. A verification that the automatic system start-up and shut-down circuitry within the PC equipment is operational, and the array DC voltage is at its design value.

c. A measurement and reporting of the minimum, maximum, and average inverter efficiency for the ten-day period as indicated by the test data.

d. An estimate of the on-site power factor of the PC equipment.

4.3 System Start-up and Shut-down:

The Contractor shall demonstrate that the manual system start-up and shut-down controls operate properly and that the PV system disconnects automatically from the utility power supply whenever a utility outage occurs. The Contractor shall perform the start-up, shut-down and disconnect tests a minimum of ten (10) times.

4.4 System Acceptance and Warranty:

The final acceptance of the PV system shall be made after installation is complete in all aspects and it has been verified that the system is performing as designed and in compliance with all provisions of this Statement of Work. After acceptance by the Government and the warranty period goes into effect, the entire PV system, including the instrumentation, shall be fit for and operate in accordnace with the system design performance requirements for a period of not less than two (2) years after Government acceptance. All system repairs required by failures not caused by misuse or accident or through fault or negligence of the Government within this period shall be made at the Contractor's expense, including, without limitation: on-site inspection, parts, labor, and transportation costs. In the event that any warranty repairs are required within the stated two-year period, the Contractor shall document any corrective actions on his part with an Unscheduled Outage Report, the format of which is given in Appendix.

5.5 System O&M Documentation

5.1 Introduction:

The Contractor is not responsible for normal maintenance of the PV system once it has been accepted by the Government. However, the Contractor shall provide the following field instruction, manuals, and schematics to assist in the system operation, maintenance, and troubleshooting.

5.2 Field Instruction:

Upon completion of the system installation, testing, and evaluation, and at a time designated by the Contracting Officer, the Contractor shall provide the services of a project engineer for a period of not less than eight (8) hours at Fort Huachuca to instruct Government personnel in the operation, maintenance, and troubleshooting of the Guest House PV system. The Contractor shall supply sufficient course material for six (6) trainees; classroom space will be provided by the Government. This training shall treat the following subjects: the theory of system operation, start-up and shut-down procedures, preventive maintenance measures and schedules, and instruction in system troubleshooting and repair. Specific attention shall be given to safety considerations and to the isolation and replacement of defective components.

5.3 O&M Manuals:

At the time of the field instruction the Contractor shall provide the Contracting Officer with six (6) typed and bound sets of system operation and maintenance manuals containing the following information:

a. An overview of the system operation, including an as-built system schematic, a description of the theory of operation, and as-built wiring and control diagrams.

b. Brochures, schematics, and descriptive data, including O&M instructions, from the supplier of each piece of equipment installed under this contract.

c. A complete parts list, including recommended spare parts.

d. A description of system start-up, shut-down, operation, and troubleshooting procedures.

e. A suggested system maintenance schedule.

f. The name, address, and telephone number of the Contractor.

5.4 Framed Instructions:

The Contractor shall post in the Mechanical Room of the Guest House a complete PV system schematic (including wiring and control diagrams) framed under glass or plastic. In addition, condensed operating instructions explaining preventive maintenance measures and schedules and defining system check out, start-up, and shut-down procedures shall be prepared in typed form, framed similar to the system schematic, and posted beside the drawings. Proposed diagrams and instructions shall be submitted to the Contracting Officer for approval prior to posting. The framed instructions shall be made available to the Government at the time of the system field instruction.

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