ERDA/NASA/1022-77/19
NASA TM-73787

THE ERDA/LeRC PHOTOVOLTAIC SYSTEMS TEST FACILITY

(NASA-TM-73787) THE ERDA/LeRC PHOTOVOLTAIC SYSTEMS TEST FACILITY (NASA) 12 p HC A02/MF A01 CSCL 14B
N78-15059
Unclas
G3/09 55548

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Work performed for
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Division of Solar Energy
National Photovoltaic Conversion Program
Under Interagency Agreement E(49-26)-1022

TECHNICAL PAPER to be presented at the
1977 Photovoltaics Solar Energy Conference
Commission of The European Communities
Luxembourg, September 27-30, 1977

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-73787		

4. Title and Subtitle
THE ERDA/LeRC PHOTOVOLTAIC SYSTEMS TEST FACILITY

5. Report Date
September 1977

6. Performing Organization Code

7. Author(s)
Americo F. Forestieri

8. Performing Organization Report No.
E-9352

10. Work Unit No.

9. Performing Organization Name and Address
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

11. Contract or Grant No.

13. Type of Report and Period Covered
Technical Memorandum

12. Sponsoring Agency Name and Address
Energy Research and Development Administration
Division of Solar Energy
Washington, D.C. 20545

14. Sponsoring Agency ~~Code~~ Report No.
ERDA/NASA/1022-77/19

15. Supplementary Notes
Prepared under Interagency Agreement E(49-26)-1022.

16. Abstract
The ERDA/LeRC Photovoltaic Systems Test Facility is designed, built, and operated by the Lewis Research Center as a national facility to serve the needs of the ERDA National Photovoltaic Conversion Program. The objective of the facility is to provide a place where photovoltaic systems may be assembled and electrically configured, to evaluate system performance and characteristics. The facility consists of a solar cell array of an initial 10-kW peak power rating, test hardware for several alternate methods of power conditioning, a variety of loads, an electrical energy storage system, and an instrumentation and data acquisition system.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Photovoltaic systems Solar cell systems	Unclassified - unlimited STAR Category 44 ERDA Category UC-63

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

* For sale by the National Technical Information Service, Springfield, Virginia 22161

THE ERDA/LeRC PHOTOVOLTAIC SYSTEMS TEST FACILITY*

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Summary

The ERDA/LeRC Photovoltaic Systems Test Facility is designed, built, and operated by the Lewis Research Center as a national facility to serve the needs of the ERDA National Photovoltaic Conversion Program. The objective of the facility is to provide a place where photovoltaic systems may be assembled and electrically configured, to evaluate system performance and characteristics.

The facility consists of a solar cell array of an initial 10-kW peak power rating, test hardware for several alternate methods of power conditioning, a variety of loads, an electrical energy storage system, and an instrumentation and data acquisition system.

*This work was supported by the Energy Research and Development Administration.

1. INTRODUCTION

The ERDA/LeRC Photovoltaic Systems Test Facility (STF) located at the Lewis Research Center provides a vital support function to the overall ERDA National Solar Photovoltaic Program. As a "breadboard" system, it allows preliminary investigation and checkout of components, subsystems and complete photovoltaic systems before installation in actual service. The STF also permits the assessment of candidate photovoltaic systems and design concepts, and can be used to determine optimum system configurations and operating modes.

This report describes the STF and its capabilities. More detail can be found in reference 1. Information obtained as a result of recent facility operation will also be described.

2. FACILITY DESCRIPTION

The elements of a photovoltaic power system are shown in figure 1. The ERDA/LeRC Photovoltaic Systems Test Facility (STF) includes all of these elements as well as an instrumentation and data acquisition system. Figure 2 is an aerial photograph of the STF which will be of some help in the following description.

Solar Cell Array. - Figure 3 is a photograph of the STF array. The array field consists of 240 4-foot by 8-foot solar cell panels mounted on variable angle (5^o-85^o) support frames. There are eight rows of 30 panels each. Each solar cell panel can be equipped with modules of nearly any design. The present array utilizes modules from three manufacturers installed in the first two rows. These two rows have a peak power rating (at 1000 W/m^2, 28^o C) of 10 kW. The remaining six rows (30 kW) when equipped with modules will bring the array capability to 40 kW peak.

The modules may be interconnected electically in various configurations. At present, the configuration is six series strings of manufacturer X, 19 series strings of manufacturer Y and 46 strings of manufacturer Z. This configuration produces an array output voltage (at maximum power point) of about 170 volts. Since the series strings are not all identical, there is a power loss due to mismatch estimated to be about 4 percent. Four wires per panel have been installed to the control room to provide flexibility in array electrical configuration.

Panel wiring is routed along wiring trays to a terminal cabinet at the end of each row. From there the wiring is routed underground through 350-

foot ducts to the control room. Each series string is connected to a solar array busbar in the control room through a switch, an isolation diode and a fuse. The output voltage of the solar array can be changed by reconfiguring the array interconnection in the field or in the control room. The array can also be electrically split into several independent arrays.

Energy Storage Equipment. - Many photovoltaic power systems require on-site energy storage. The STF has 48 kWh of lead-acid storage batteries for this purpose. The battery cells are of a deep-discharge-cycle-duty type, with lead-antimony positive plate grids and calcium alloy negative plate grids. The battery is housed in a battery shed immediately adjacent to the control room. The battery shed is provided with forced air ventilation and a safety alarm which is triggered by loss of ventilation. Plastic acid-resistant trays are also provided to contain accidental acid spills. Room is available in the shed to expand the on-site storage to as high as 500 kWh.

The battery may be charged either from the solar array or from the electric utility grid. Each charging method requires separate charging equipment. For the STF as it is presently configured, the battery is charged by a commercial battery charger operating from the utility power source or from a shunt battery charge controller when charged by the solar array.

Power Conditioning Equipment. - Although the STF is a flexible power system and can be interfaced with virtually any type of power conditioning equipment, the initial test systems were assembled with a single-phase 5-kVA self-commutated inverter and a single-phase 8 kW line-commutated inverter which is transformer-coupled to a load bank and to the local electric utility distribution network. For both types of inverters it was found necessary to connect a capacitor across the array output (or inverter input) for proper operation. In addition the line commutated inverter requires a series inductance to increase the performance to acceptable levels (2).

Electric Utility Distribution Network and Loads. - The interface with the electric utility is achieved through proper matching transformers and circuit breakers. Various loads, which are used as part of the systems tests, can be supplied either by the solar array and/or the utility. With the line commutated inverter in use the load sharing is accomplished as described below. When the solar array can supply more power than is called for by the load the excess power is fed into the utility grid. When there is insufficient power from the solar array the load accepts what is available from the array and makes up the difference from the utility network automatically.

In the case of the self-commutated inverter, parallel operation as described above is not possible. In this case the load is supplied either by the array or the utility and this is accomplished through automatic switches. A self-commutated inverter that would permit sharing the loads with the utility is under development.

Instrumentation and Data Acquisition System. - The Instrumentation and Data Acquisition System (IDAS) includes transducers for measuring electrical parameters (voltage, current, power, reactive power), temperature, weather parameters (wind speed, wind direction, air temperature, humidity), and insolation. The initial IDAS included a data logger interfaced with the LeRC IBM-360 computer. Recently, a combined microprocessor minicomputer data acquisition and display system has been installed. It will complement the initial system by providing on-line results during STF operation. A portion of the initial IDAS can be seen in figure 4. This equipment is installed in the STF control room housed in two trailers approximately 350 feet east of the solar array field.

3. SAFETY CONSIDERATIONS

General LeRC safety procedures with regard to both ac and dc circuits of comparable current and voltage are applied to the STF. The solar array field is regarded as a dc substation and is enclosed on all four sides by an 8-foot-high chain-link fence. The steel solar cell panel mounting frames are connected to array field ground through a buried copper cable network and ground rods. Frame grounding is for limiting damage from lightning and for personnel safety. Negative terminals of the series strings of solar cell modules are connected to the array field ground. A more detailed description of these connections, including photographs and circuit diagrams, is given in reference 1.

As discussed earlier each series string of the array is connected to the solar array busbar through disconnect switches. These switches are opened and tagged with a warning when work is being done on panels within the series strings. A master switch to isolate all array dc power from the control room side of the busbar is also provided. This switch is opened and tagged when work is being done on the dc lines within the control room.

Safety procedures for maintenance and inspection of the solar array have been set up. The preferred method is to do all of this work at night when the array is not producing power. An alternate method for daylight has also been approved. This includes isolating the portion of the array to be worked on with the switches mentioned above and further by covering the panels with special reinforced black plastic, held in place by elastic cord. Finally the isolated panels are short circuited at the output terminals.

4. STF INFORMATION

Since the STF has been installed a number of factors affecting the solar cell array such as wind, ambient temperature, snow and dirt were investigated. Also, radiated electromagnetic interferrence and power losses were determined (3).

The temperature of the solar array depends on the way the solar cell modules are packaged by the manufacturer and the way they are mounted in the STF. The temperature of one type of module with an epoxy-glass substrate which was mounted on plywood with 1/8" standoffs was typically about 30° C above ambient temperature. Another with a finned aluminum back ran about 10° C above ambient temperature. These measurements were made with insolation of about 1000 W/m^2 and wind velocity of about 8 miles per hour.

Snow was found to adhere better to the epoxy-glass substrate modules than to the aluminum substrate modules even though both types used a silicone rubber encapsulant. The array for all of these observations was maintained at an angle of 41° to the horizontal.

The effect of dirt on the solar cell modules was very dependent on the construction of the module cover. After about three months exposure in the STF the power loss due to dirt on the modules was about 8%. With washing, about five or six percentage points of this loss could be recovered. A more complete report on this subject can be found in reference 4.

Although the effect of environmental factors on the STF are of primary interest it is also necessary to investigate the effect of the STF on the environment. For example, radiated electromagnetic interference (EMI), which could affect communication, was investigated as a function of array size and system components operating. Preliminary results (5) show no EMI problems were detected in operating either type of inverter with the solar array. The EMI levels measured were well below the limits established by the Federal Communications Commission for spurious and harmonic emissions.

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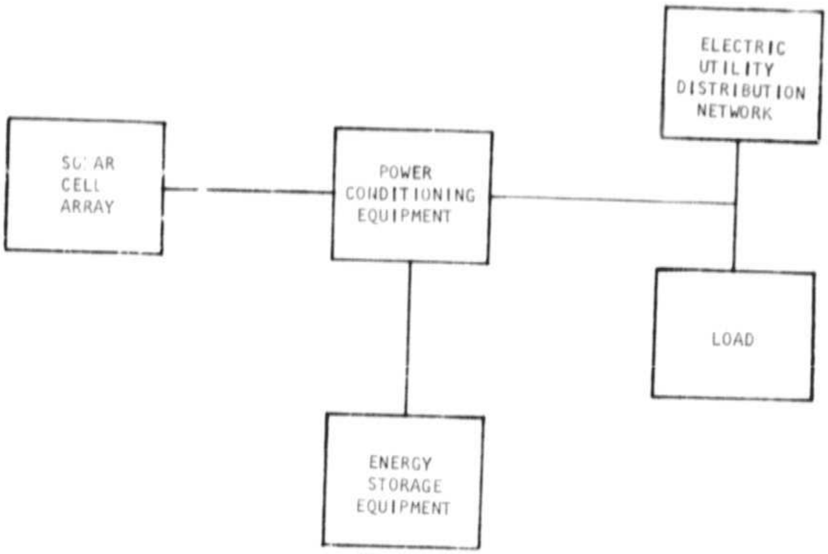

Figure 1. - Elements of a Photovoltaic Power System

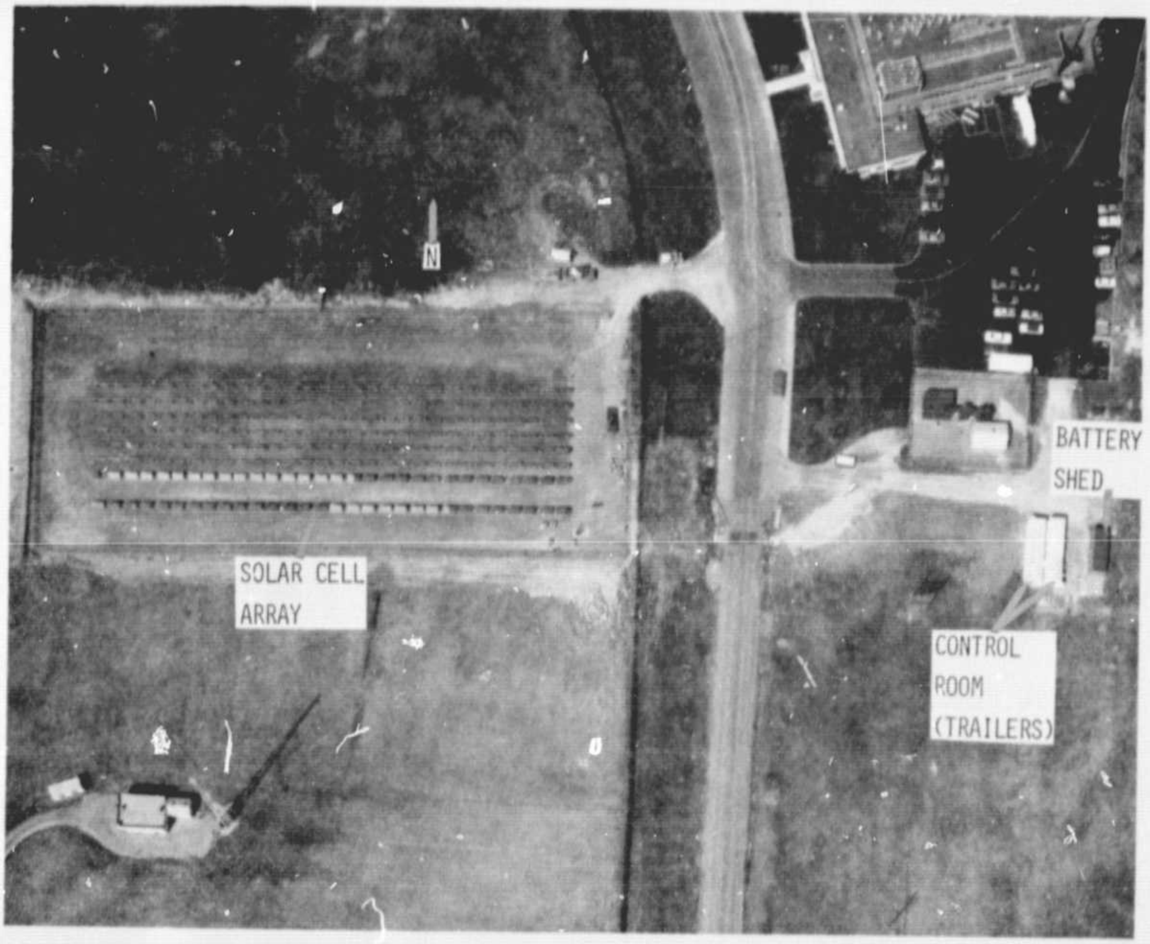

FIGURE 2. - ERDA/LeRC PHOTOVOLTAIC SYSTEMS TEST FACILITY (AERIAL VIEW)

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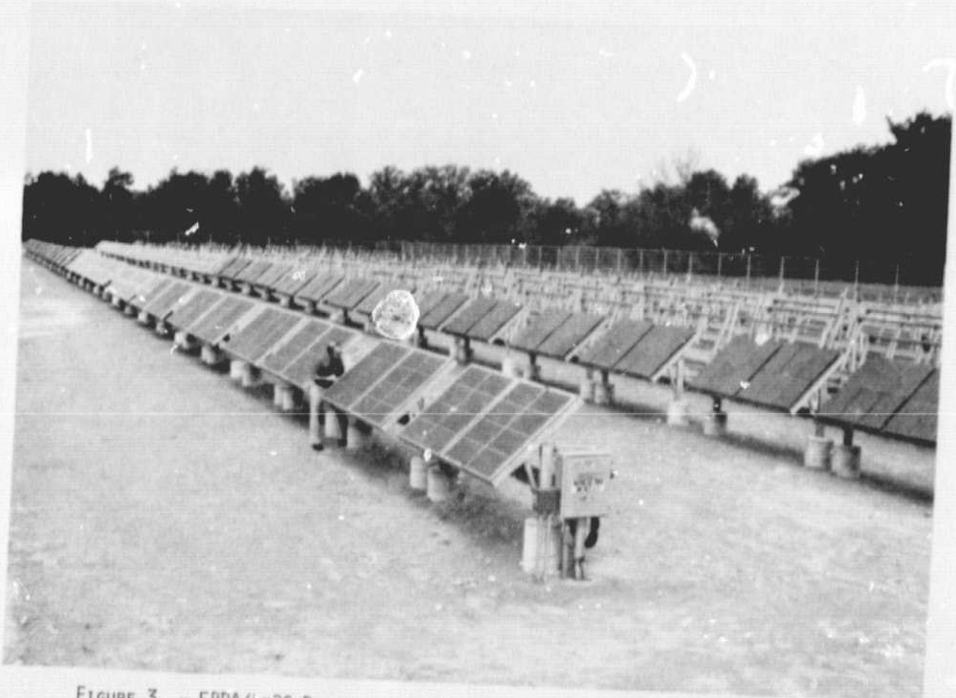

FIGURE 3. - ERDA/LeRC PHOTOVOLTAIC SYSTEMS TEST FACILITY (SOLAR ARRAY FIELD)

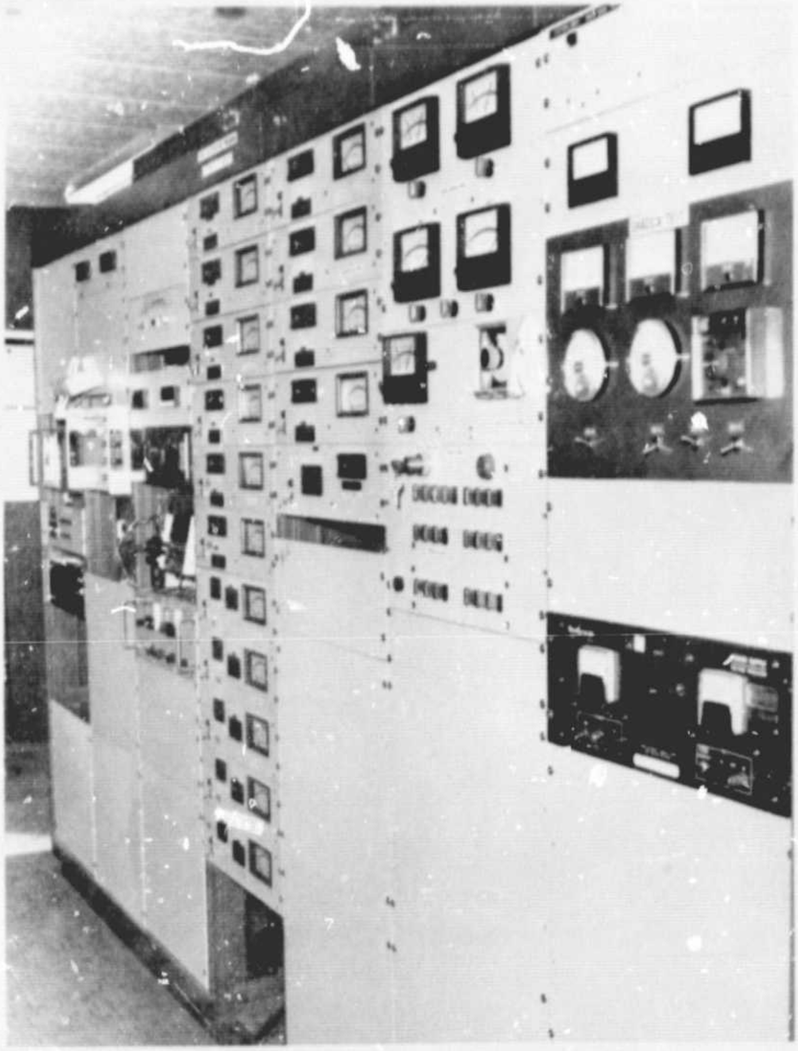

FIGURE 4. - ERDA/LeRC PHOTOVOLTAIC SYSTEMS TEST FACILITY INSTRUMENT AND CONTROL ROOM

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