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Sunsine300 AC Module

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EXECUTIVE SUMMARY

Under PVMaT 4A1, Ascension Technology (AT) is developing the SunSine300 AC PV module. This product is expected to go into production and ship in the summer of 1997. Work under PVMaT 4A1 began with the proof of concept prototype developed under a previous Sandia National Laboratories contract. Though the core inverter topology has remained the same, significant redesign has been done to produce a manufacturable product ready for commercialization.

The SunSine300 is a powerful PV module designed with integrated power and control electronics which make it a grid connectable AC power source. Safety considerations require that the units be wired into the home electrical service through a dedicated circuit breaker. From a functional perspective, the SunSine300 is an appliance that connects to the household wiring to provide electricity to the household with excess sold back to the grid.

AT's goals in this project are as follows:

- Meet UL 1741
- Obtain FCC Class B verification
- AC Module system design and development
- Inverter design advancement
- Design for manufacture
- Design for reliability
- Design for serviceability
- Demonstrate commercialization through production and sale of approximately 100 units

UL Listing

In November of 1996 the results of a UL preliminary investigation of a SunSine300 prototype were received. This was a construction-only evaluation of

the product. A number of deficiencies were found and corrected before proceeding to the full UL investigation.

FCC Compliance

In the fall of 1996 a prototype of the SunSine300 was tested and found to comply with FCC class B requirements. The purpose of this test is to assure that the SunSine300 will not interfere with receivers (television, radios, hearing aids, etc.) in the home. The production version will need to be retested but it is expected to radiate less than previous versions due to design improvements.

AC Module System Design and Development

AT has designed a complete line of Balance of Systems (BOS) hardware for the SunSine300. This assures customers one stop shopping for a complete photovoltaic system.

Design Advancement

A number of design and performance advancements were made however four accomplishments stand out.

- THD dropped from 5% to 2%.
- A method was devised to eliminate false detection of zero crossings which could damage the inverter
- Significant improvement was made in anti-islanding with the addition of the proprietary *ZEBRA* technique, developed by AT.
- Enclosure redesign for thermal performance, manufacturability, and UL and FCC approval.

Design for Manufacture

In parallel with the overall design effort, design for manufacture has been a continuing consideration:

- PCB designed to accommodate automated production and assembly techniques

- Enclosure is designed for production using a variety of casting methods enabling manufacturing optimization at all foreseeable production volumes.
- Enclosure designed to simplify assembly and reduce inventory of miscellaneous hardware.

Design for Reliability

Extensive testing has been and continues to be done in phase 2 in an effort to discover failure modes and susceptibility to aging. These include:

- Field testing at Sandia National Laboratories, NREL, and AT's Boulder office.
- Thermal testing at our Waltham MA, site targeted at characterizing the influence of enclosure design factors on internal temperatures.
- Accelerated aging and environmental testing using ASE Americas facilities.
- UL testing including overload, temperature and environmental tests.
- Accelerated aging using HALT/HAST methods.[1] This work was funded by Sandia National Laboratories.

Design for Serviceability

The SunSine300 has been designed to be easily and safely serviced. It is expected that should service be required, it will be on the inverter with its numerous connections and components. The inverter has been designed with quick connect/disconnect electrical connections on both the AC and DC sides. The number of fasteners was minimized, only four are used. Service will consist of removing a defective inverter, swapping in a new or refurbished one and sending the defective unit to the factory for refurbishing.

INITIAL PRODUCTION RUN

PVMaT4a provides support up to and including initial production. AT has arranged for approximately 20 utilities to cost share the production of the first 100 units produced in pilot production.

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1 HALT is Highly Accelerated Lifetime Testing
HAST is Highly Accelerated Stress Testing

INTRODUCTION

The PVMaT program has enabled Ascension Technology (AT) to develop a fully-integrated, grid-tied, AC photovoltaic module designed for manufacture and compliance with safety codes and standards. The SunSine300 produces sinewave ac power from AT's 300-Watt inverter factory-mated to a powerful PV module. In the summer of 1997 Ascension Technology will introduce this new advancement in photovoltaic system technology to the marketplace.

The appeal of photovoltaics (PV) is that it is arguably the most environmentally benign way to generate electricity. Further to its advantage, deployment of PV systems can be on dual-use space such as residential and commercial rooftops or as shade structures over parking lots. The approach typically taken for building rooftop grid-tied PV systems has been to mount PV modules on the rooftop with dc wiring routed to a central dc-to-ac inverter placed somewhere in or on the skin of the building. This type of system has been very effective, however it has several disadvantages: (1) high voltage and/or high current dc wiring is required, (2) municipalities may not be equipped to address the associated inspection and safety issues, (3) dc balance-of-systems (BOS) hardware is less common and more expensive than its ac counterpart and, (4) these systems require specialized engineering and design support. Finally, hardware is not available today to configure systems of this type in sizes smaller than approximately 2kW. As a result, the entry-level cost of a grid-tied PV system is out of reach of many who would like to own their own green power generation.

The concept of an AC module was born from the desire to address these PV system deficiencies and make grid-tied PV systems more affordable, bring them in line with traditional electrical wiring products and practices, and make them more accessible to the green power segments of society. The SunSine300 permits installation of PV systems at a much lower entry level price and eliminates the need for specialized engineering, reducing market barriers to grid tied PV technology.

In 1991 Ascension Technology began its initial examination of the technical issues surrounding design of a small inverter for the SunSine300. Late in 1993, with funding from Sandia National Laboratories, Ascension Technology began an in-house development effort to construct a working prototype and demonstrate the technical feasibility of the SunSine300. In the spring of 1995 a fully functional SunSine300 prototype was delivered to Sandia National Laboratories.

The Department of Energy's Photovoltaic Manufacturing Technology (PVMaT) project, PVMaT 4A1 has provided the vehicle to advance and commercialize this technology. Late in the summer of 1995 AT began its development of a commercial version of the SunSine300. The requirements for the success of a first-generation SunSine300 are: cost reduction, reliability, manufacturability and agency approval (Underwriters Laboratories Listing and FCC Class B certification).

AT's PVMaT project progresses from technology development to pilot production of the commercial-ready SunSine300. There are 19 cost-sharing utility partners involved in the test and pilot production phases of the project. Evaluation units have been and continue to be tested in the environmental chambers at NREL and ASE Americas. ASE Americas is providing this service as a cost-sharing partner in the project. At the completion of our project, AT will manufacture and deliver approximately 100 UL listed, FCC Class B production units to our cost-sharing utility partners for field evaluation. Each of these utilities has agreed to purchase between one and twenty AC modules for testing and evaluation. A list of participating utilities is included in appendix A.

PVMaT4a PROGRAM PROGRESS

UL LISTING

From the outset AT intended the SunSine300 to be UL listed. In the fall of 1996 the first prototypes designed for UL compliance were built. As a guide, the December 22, 1993 proposed First edition of the Standard for Power Conditioning Units for Use in Residential Photovoltaic Power Systems, referred to as UL 1741, was used. This was supplemented by direct conversations with UL.

At the recommendation of UL, AT had a preliminary investigation done. The preliminary investigation is a construction only review of the product. Items such as PCB trace spacings, materials of construction and component spacing are reviewed. At the end, UL prepared a report listing all of the product's deficiencies related to UL listing. The next several months were spent addressing these design deficiencies and others that AT became aware of as its engineers became more familiar with UL 1741.

When UL was made aware that AT was developing a power conditioner with PVMaT support, they invited AT to participate on an Industry Advisory Committee (IAC). The purpose of the committee is to bring industry experience into the working group developing the UL 1741 standard. Being on the committee has benefited AT by providing a better understanding of how UL evaluates products and keeping the company up to date on changes to the standard. Shortly after receiving the results of the preliminary investigation AT received the updated, October 1996 draft of UL1741.

Deficiencies were found which fall into several categories: redesign, documentation, and non-recognized components. Examples follow.

Redesign

Examples of redesign issues identified are PCB spacing revisions and correction of wire routing problems. In this case part of the PCB was too close to the grounded enclosure. This was easily corrected in the next design revision by modifying the casting. Several wire routing violations were pointed out to us. In particular, there were several cases where wires ran too close to uninsulated live components. Design modifications were implemented to correct this problem.

Documentation

Labeling deficiencies were flagged and corrective action taken. Several design issues were resolved by modifying wording in the instruction booklet. For example, overcurrent protection for an entire branch circuit is not provided in the SunSine300. Rather than trying to build it into the inverter, it was sufficient to add a statement in the instruction booklet that specifies to the installer the type of overcurrent protection that must be installed externally at the users site.

Non-Recognized Components

A number of non-recognized components were flagged. Some were custom components and some were off the shelf. In one case, a manufacturer had represented that their parts were UL recognized. Careful evaluation of their documentation revealed that this was incorrect. This was brought to our attention in the preliminary investigation. AT notified the manufacturer and they made the proper arrangements to have the part recognized.

AT has worked with a connector manufacturer to develop an AC connector for the SunSine300. Though not UL recognized, AT was under the impression that a review of its construction would be sufficient. The preliminary investigation revealed that the AC connector would need to be recognized separately. The listing of this product was initiated by AT shortly after the preliminary investigation was completed.

All items in the preliminary investigation were addressed in Phase 1. UL listing has continued into Phase 2.

FCC CLASS B VERIFICATION

Switch mode power conversion devices such as the SunSine300 produce electrical noise over a wide frequency range. The primary noise sources are high speed edge transitions, their harmonics and, for units with microprocessor controls, the microprocessor clock and its harmonics. If not kept contained within the device, this noise, commonly referred to as electromagnetic interference (EMI), can interfere with receivers such as televisions, cordless phones, and radios. Since these receivers are used for communication, the Federal Communications Commission (FCC) regulates noise emitters to prevent degradation of the electromagnetic spectrum.

The FCC has two device categories. Class B are devices used in residences, where there tends to be a high density of receivers. Class A devices are used elsewhere where the density of receivers is less. Class A is a less stringent rating than class B. Because the SunSine300 is designed for residential use it must meet class B guidelines.

EMI can get into receivers in two ways: radiation through the air and conduction through electrical wiring. When high frequency noise is generated in a conductor that conductor can act as an antenna and radiate the noise into the surrounding environment. The noise can also propagate along the conductor and find its way onto the power cord.

The SunSine300 has been designed to prevent EMI from escaping from the enclosure. The two methods for doing this are filtering and shielding. One of the functions of the grounded aluminum enclosure is to provide shielding. When radiation strikes it, it is absorbed. This is very effective. A difficulty can arise where there are holes in the enclosure, for example, cable outlets and weep holes. However, testing has shown that due to the location, size, and shape of the holes, the SunSine300 enclosure provides excellent shielding and passes the FCC Class B radiated emissions test.

Conducted EMI is prevented by using electrical filters. These are used on the AC output and DC input of the inverter. After initial testing of the inverter it was discovered that the filters were working well at lower frequencies but that the magnetic cores of the filter inductors were ineffective at high frequency, reducing the filter's effectiveness at high frequency. As a result a high frequency low pass filter was developed to block the high frequency noise.

It is important to note that though the PV modules are electrically isolated, filters are still required on the DC side because the conductors in the PV module make good antennas. This is because some of the harmonics of the switching frequency (the primary contributor to EMI) have wavelengths approximately equal to the length of the conductors making them efficient radiators. Conducted EMI, with this wavelength, that finds its way up to the module wiring will be radiated, interfering with nearby receivers.

Problems identified in early prototypes have been resolved. In October 1996 the SunSine300 passed conducted emissions with a margin of 2.7dB and radiated with a margin of 3.9dB.

AC MODULE SYSTEM DESIGN AND DEVELOPMENT

AT has advanced the design of system components, including connectors, the PV Source Circuit Protector (PVSCP™) and our RoofJacks™ mounting hardware, all for use with SunSine300 system installations. See component drawings in Appendix B.

The SunSine300 will be equipped with a factory-installed pair of 3-pin connectors that have been developed during this project. These will vastly simplify field wiring of SunSine300 arrays, as the AC modules can be plugged together to make parallel connections of their ac output. The number of SunSine300s that can be parallel-connected is limited to six by the gauge (12 AWG) of the connector wire. These connectors use tray cable with color-coded jacketing of conductors for ac line (black), ac neutral (white) and equipment ground (green), in an overall black sheathing. The ground pin is the first-to-make and last-to-break. Samples of this connector have been produced and used with AC module prototypes. The connector will be submitted to Underwriters Laboratory for investigation during Phase 2 of PVMaT4a. AT intends for this connector to qualify as a load-break disconnect.

AT manufactures a line of UL-listed PV Source Circuit Protectors that are used in dc PV arrays to facilitate compliance with the National Electrical Code and enhance system safety. New versions of the PVSCP™ have been developed for use with AC module systems. In addition, mechanical changes to the enclosure have been implemented, offering greater flexibility for field-wiring conduit interfaces, improved weep holes to insure no water build-up inside, and a significant re-design of the enclosure cover. The cover now uses only one fastener and allows the PVSCP™ to be padlocked if desired. These new versions of the PVSCP™ are also UL listed.

A new version of the RoofJacks™ mounting brackets was also designed. The new RoofJacks™ eliminates pull-out forces on the fasteners holding the RoofJacks™ to a pitched roof. It also accommodates a 1.25-inch pipe nipple, used as a wiring pass-through and shelter for the mated connectors of adjacent SunSine300s. The SunSine300 will come factory-equipped with the mounting pins necessary for RoofJacks™ mounting.

DESIGN ADVANCEMENT

As called for In Phase 1 Task 2 of the PVMaT contract the overall design was reviewed and improved. There were several design advancements of particular note. These took the inverter from the Sandia-funded Proof of Concept prototype (POC) to production prototype. Highlights of these changes are discussed below.

Enclosure

The POC prototype was housed in a hastily designed enclosure with the transformer housed separately. Ascension Technology redesigned the circuit board and subassembly layout to maximize packaging density. Care was taken to assure that the enclosure height would be such that two modules could be stacked back-to-back without the inverter housing on one module touching the back glass of the other.

The enclosure design must take into account thermal considerations, sealing, size constraints, design for manufacture, UL requirements, and FCC requirements. AT worked with an industrial designer to develop a packaging solution.

Zero Crossing Detection Noise Immunity

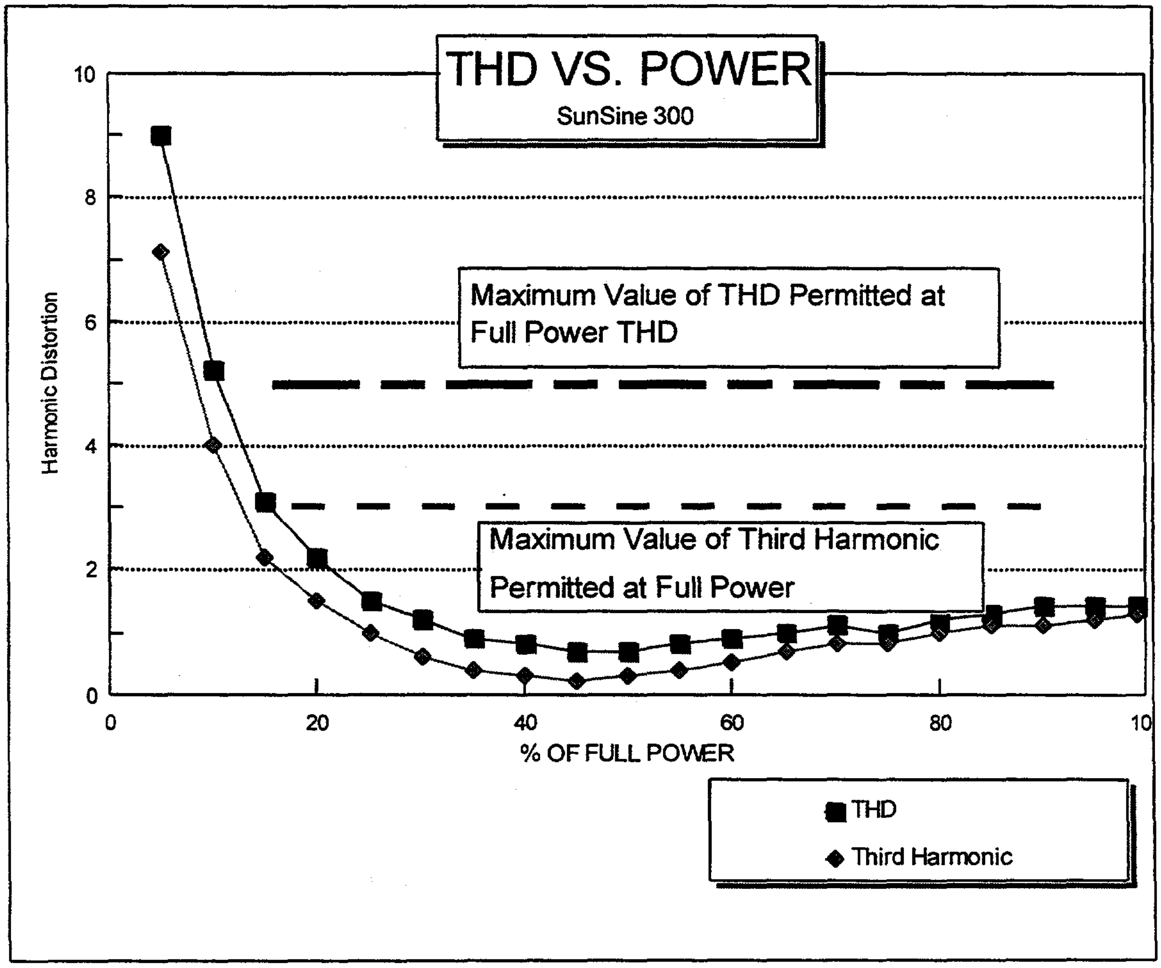
The POC prototype had a defect in its zero crossing detection circuitry which made it susceptible to noise. It occasionally detected false zero crossings short circuiting the inverter bridge. Under certain circumstances this caused catastrophic failure of critical inverter components. The cause of the problem was determined and corrected and no false detections are known to have or are suspected of having occurred.

THD

In the POC prototype, THD hovered right around 5%, the design target, and the maximum permitted in UL 1741. For production units this was unacceptable because there was no margin for error. A change to the control feedback as well as some proprietary changes brought THD down to under 2% at full operating power leaving a comfortable margin.

Figure 1

Harmonic Distortion vs. Power



Anti-Islanding

Anti-islanding is a primary concern of utilities. In addition to standard passive over/under voltage and over/under frequency detection methods, a frequency shift and proprietary "ZEBRA" active anti-islanding schemes were added to the

SunSine300. To date the ZEBRA method has not been defeated. In laboratory tests each of the other methods, alone, has been defeated by carefully matching the load and then shutting down power.

Over/under voltage circuitry can lead to nuisance tripping if it is not properly designed. Some intelligence has been added to the firmware to monitor voltage and assess how far out of range the voltage is. For minor sags, more time is allotted before shutting down the inverter. For severe over/under voltage, the unit trips almost instantly. The trip points are designed to comply with IEEE 929 and UL 1741. See plot below.

Figure 2

Voltage error trip times

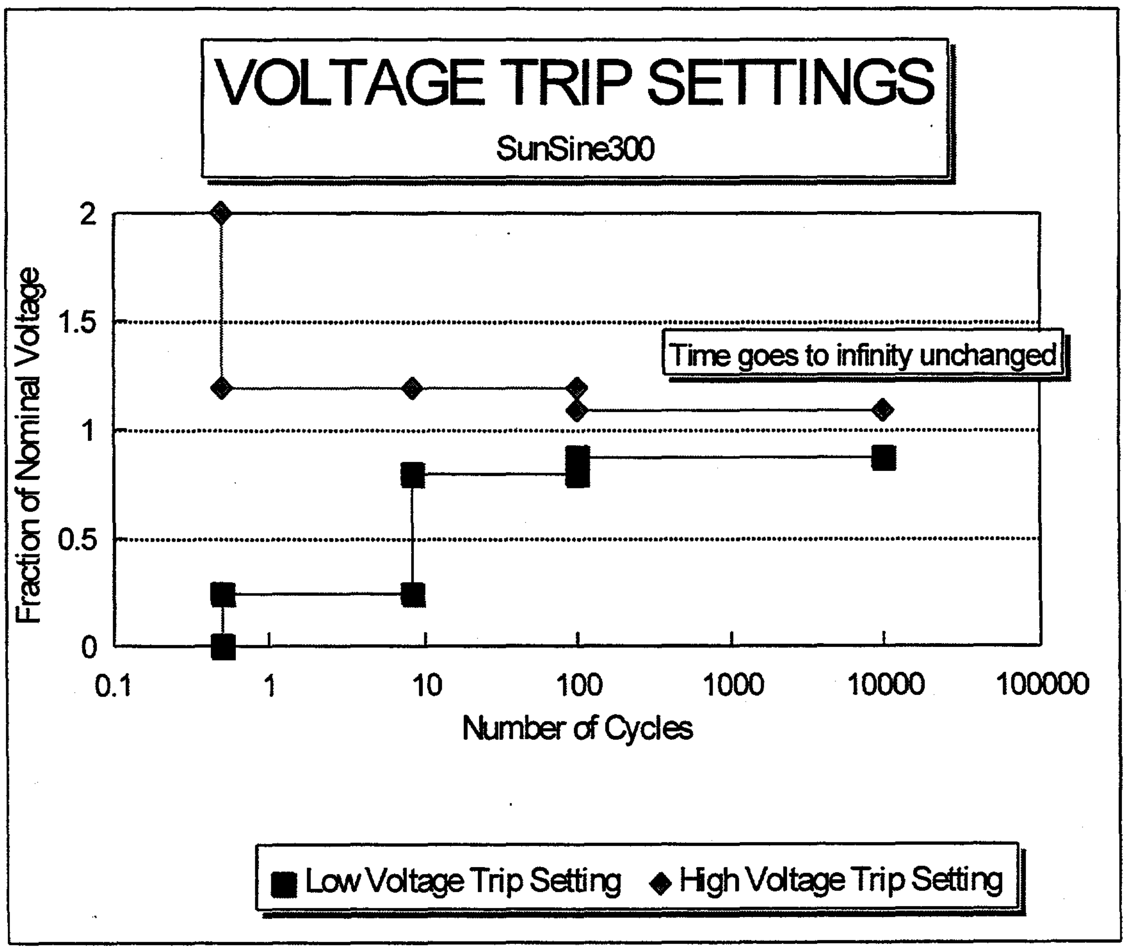
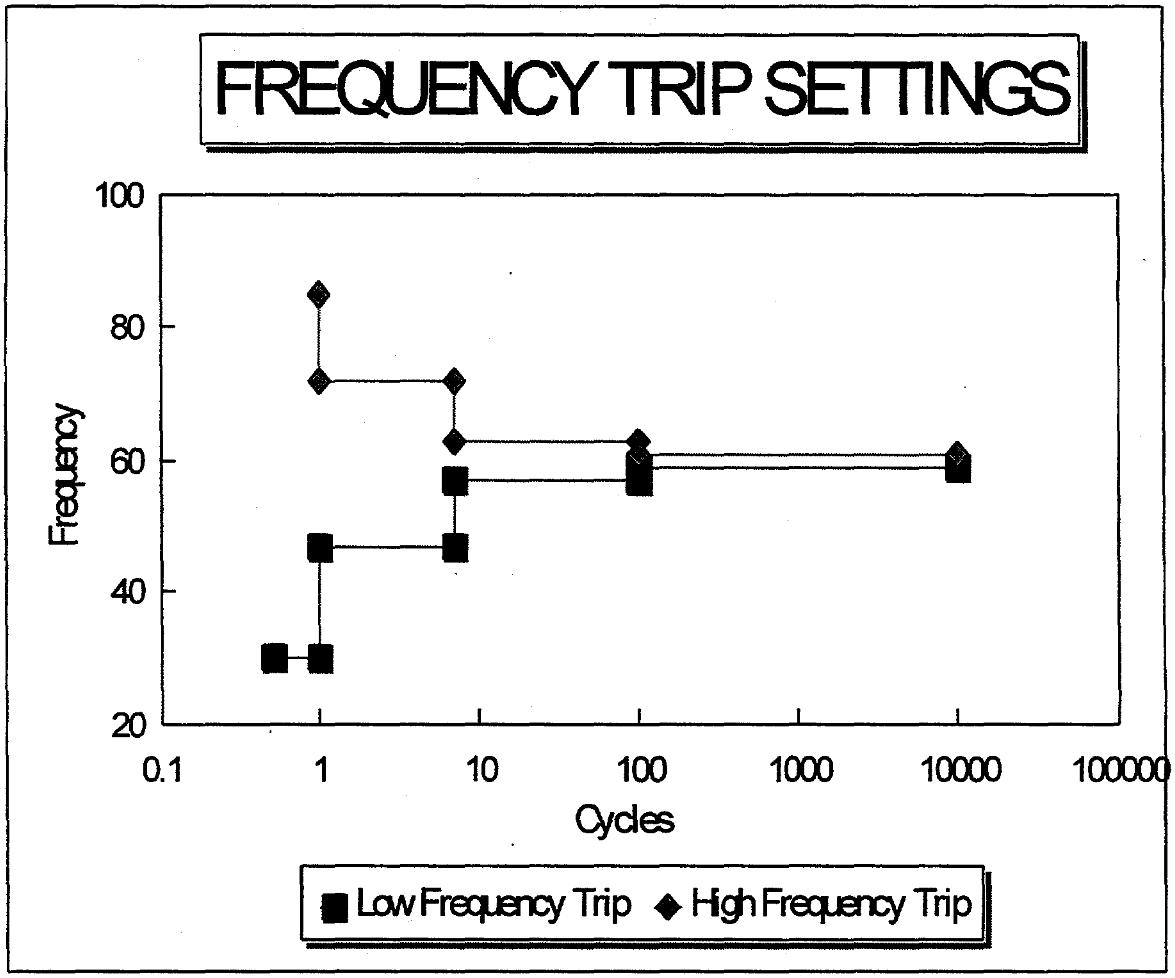


Figure 3

Frequency error trip time



DESIGN FOR MANUFACTURE

During the course of Phase 1, manufacturing issues were taken into account in all aspects of the design. Prototype PCBs had been hand stuffed and soldered. Production prototypes were designed for automated production tooling. The enclosure is designed both for ease of manufacture and to ease assembly of inverter subsystems. The inverter assembly is designed to dovetail almost seamlessly into ASE Americas module production, taking the place of the diode housing that currently is mounted to the back of the modules.

Production of the PCBs themselves is well automated in state of the art board fab houses. For little additional cost inspection and bed of nails testing of the unstuffed boards can be added to identify solder bridges and other manufacturing problems.

There are a variety of assembly options. AT is using through hole technology[2]. Parts of this type are typically stuffed in a PCB by hand, by hand assisted by a semi-automatic pick and place machine, or with a fully automated pick and place machine. Choice on method is dependent upon volume. In low volume, hand stuffing is used because it requires very low up front set up with its associated cost. Semi-automatic pick and place is less costly on a per board basis but there is a set-up cost associated. It has the added advantage of lowering board stuffing errors. Automatic pick and place has a high set-up penalty but the only human intervention required involves fixing the machine if it jams. The piece price and error rates are both low. Board layout was done utilizing component spacing and tooling holes that are compatible with either fully automatic or semiautomatic pick and place production machinery thus supporting smooth ramp up to higher volumes.

AT's PWB geometry is designed for compatibility with wave solder equipment. Wave soldering is an automated soldering process that is significantly less costly and more reliable than hand soldering.

The enclosure design is critical to simplifying the assembly of the AC module. It is designed for manufacture and to act as skeleton for the rest of the inverter. Judicious use of machining and casting in of bosses has minimized the need for countless stand-offs and fasteners. Layout of subassemblies has been carefully done to make final assembly simple and quick.

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[2] Mature PCB technology where the leads of chips extend through the PWB and are soldered from the bottom of the board. Components can only be placed on one side of the board and they are larger than surface mount components.

The enclosure is made of cast aluminum. Several casting processes are available depending upon production volume. AT is using an air-set sand casting process. Should volume rise substantially, die casting can be employed. It has a higher tooling cost but a much lower piece price.

The casting requires some machining which is done with automated machine tools. A common misconception is that machining should be minimized in production parts. If machining can be avoided altogether it should be. However, with automated machine tools, the primary cost resides in set-up and mounting the parts in the tool. These are fixed costs that are incurred whether one or many machine operations are performed. The variable cost of additional machine operations is actually quite low. This has been taken advantage of in the design of the enclosure. Once it was determined that machining could not be avoided the designers did not hesitate to add machining steps that were advantageous. For example stand-offs were built into the casting to be drilled and tapped, as were a variety of other mounting structures. This reduced inventory and the associated overhead. Also by reducing loose hardware that must be added during assembly, the likelihood of metal parts being unknowingly dropped into the enclosure was reduced.

The enclosures are sent to the assembly house where the inverters are tested and assembled. In Phase 1, first generation test equipment was developed to test stuffed boards and partially assembled enclosures. The equipment includes a "bed of nails" mounting to functionally test the PCBs before they are conformally coated. If any rework is required it can be done without having to use messy strippers. The final assembly will then be retested. They are then sent to the module manufacturer, ASE Americas, for final assembly. Due to design revisions, the tester will require upgrades in Phase 2; these are not expected to be costly.

The inverter is designed to attach to the module much as the diode housings on ASE's standard module are. As a result the production flow for final assembly of the SunSine300 is almost identical to that of the standard module. This will minimize the need for retraining personnel and capital expenditures on production equipment. Packaging and shipping will be handled by ASE Americas in the same way as it has been for their standard large area PV modules.

DESIGN FOR RELIABILITY

The environment on the back of a PV module is extremely harsh. Both high and low temperatures are enhanced by the PV module. On winter nights, the module temperature drops below ambient due to radiative cooling. On hot summer days module temperatures 30°C higher than the ambient air temperature have been measured. These temperature extremes combined with the long lifetime expected of the inverter demand a very robust design. AT has done a great deal of testing and responsive redesign in order to insure development of a reliable AC module. Test regimens of note include:

- Testing targeted at optimizing the thermal performance of the enclosure.
- Field testing at Sandia National Laboratories, NREL, AT's Boulder office, and at locations chosen by two of the cost sharing utility partners.
- Environmental testing supported by PVMaT with ASE Americas cost sharing and facilities support.
- Accelerated aging using HALT (Highly Accelerated Life Test) and HAST (Highly Accelerated Stress Testing) test techniques. (Done during phase 2 with Sandia National Laboratories funding, see final report. [3])
- UL testing including operational overload and over temperature tests, and environmental chamber testing. (Done during phase 2, see final report.)

[3] HALT - Highly Accelerated Life Test HAST - Highly Accelerated Life Test

Thermal Testing

In normal operation, it is thought that the electrolytic capacitors will be the component that limits the lifetime of the inverter. Their failure modes are well understood, the primary one being a simple function of temperature. A thermal study of the enclosure was done to determine how to minimize thermal coupling between the PV module and the inverter enclosure in order to reduce the internal temperature. Design modifications were found that are expected to increase lifetime substantially, see Table 1. A paper describing the study was given at the NREL PV Reliability Workshop in 1996. It should be noted that this testing did not take all thermal effects into account and we would expect slightly shorter lifetimes based upon the capacitor ratings. However, according to the manufacturer, improved manufacturing methods have more than doubled the life expectancy of the capacitors without the manufacturer changing the rating. This suggests that even using the 2000 hour capacitors the design life of the inverter will be well-matched to that of the module.

Table 1

Capacitor lifetime summary

Capacitor lifetime in Years	Reference Case	Modified Enclosure
2000Hr, 105°C	14.9	17.5
5000Hr, 105°C	37.2	43.7

Field Testing

Field testing of units has been going on at a number of sites in different parts of the country. Operating units are at Sandia National Laboratories, NREL, AT (Boulder), and Minnesota at one of the cost sharing utilities.

Environmental Testing

Inverters were subjected to the same battery of tests as is specified for modules in UL1703. These tests subject the product to a variety of temperature and humidity extremes. In two of the tests, temperature cycling, far in excess of what would be encountered in the real world, is added to accelerate aging of the products. The following tests were performed:

- Humidity Freeze: The chamber containing the product is cycled from -40°C to +85°C/85% relative humidity. Each cycle is conducted over a 24 hour period and repeated 10 times.
- Thermal Cycle: Temperature is cycled rapidly from 85°C to -40°C. The test subjects the sample to approximately 6 cycles per day for 200 cycles.
- Damp heat: The sample is subjected to 1000 hours of damp heat. In this test the temperature is held at 85°C and the relative humidity is held at 85%.

After testing all but one of the units were fully operational. Some did not pass hipot tests. Problems were identified and solved in Phase 2.

DESIGN FOR SERVICE

The SunSine300 has been designed for safe and easy serviceability. The inverter can be quickly removed from the module with a single tool. There are no exposed AC or DC conductors.

A service call will be handled by sending a service person to the site. They will remove the inverter, test the module to confirm that it is working properly, and replace the inverter with a new or refurbished unit. The malfunctioning unit will then be shipped back to the factory for refurbishment. Should the module be found to need service, the entire unit, module and inverter will be sent back to the factory for repair. The service call can all be handled by a technician or trades person with very little training. No engineer need be involved at the repair site.

SUMMARY

This document summarizes the work done to complete Phase 1 of AT's PVMaT 4A1 project. All required tasks are completed and work is progressing rapidly on Phase 2. Production of UL listed SunSine300 AC modules is expected to commence in the summer of 1997. The table below summarizes the required tasks for PVMaT 4A1 Phase 1.

Table 2
Task Summary

TASK NUMBER	TASK DESCRIPTION
1	**Utility Design Critique** -Send surveys to cost sharing Utilities for feedback on design -Incorporate utility responses into a design specification -List desirable capabilities for a next generation version
2	**Module Scale Inverter Design Advancement Rev. 3** -Reduce Thd. -Incorporate bypass diodes -Reduce cost -Reduce size -Produce 12 units for UL testing, FCC testing, and performance testing at Sandia and NREL. -Produce documentation including BOM, efficiency measurements and THD.
3	**Module Scale Inverter Enclosure Development** -Produce design concept -Build mock-ups and select best

3 (Cont.)	-Build prototypes -Assemble prototypes into complete inverter and test.
4	**UL Testing of Module Scale Inverter** -Submit prototype to UL for Preliminary Investigation (PI) -Incorporate results of PI into prototype -UL testing of prototype -Recognition of inverter NOTE: This task specifies that AT will develop a UL recognized inverter that will be mated to a UL recognized PV module to create a UL listed AC module. It was later learned that to get an AC module UL listed, the inverter and module must be tested together. This has been successfully done
5	$300W_p$ Module Manufacture -Manufacture 12 300 Watt PV modules by sorting cells.
6	Assembly of Ten AC PV Module Prototypes -Assemble ten AC PV modules at ASE Americas. -Use Rev 3 PWBs -Use prototype MacroPulse connectors.
7	AC PV Module Testing -Perform environmental testing of prototypes including humidity freeze, damp heat and thermal cycling. -Do outdoor performance measurements at sites to include NREL , Sandia, and AT. -FCC class B testing -Design modifications to correct deficiencies found in FCC testing
8	AC PV Module System Design and Development -Develop quick connect connector in partnership with Alden Products. -Modify existing PV Source Circuit Protector (PVSCP) for use with AC modules. The new unit is to be UL listed.

	-Develop mounting system based upon the established AT Roof Jack™ mounting system specifically designed for use with the SunSine300. -Determine the best options for interconnection to the utility. -Produce a design report for the AC Module System including: Bill Of Materials, cost comparison with conventional roof mounted systems, and all related drawings.
9	Production of 12 AC PV Modules -Assemble 12 SunSine300 AC PV modules at ASE Americas -Develop manufacturing techniques for production of 125 units in the pilot production run.

Table 3

Deliverables Summary

Deliverable	Description
D-1.1	Deliver target technical specs for AC Module (Task 1) This deliverable provided a clear set of guidelines from which to engineer the SunSine300. It also assured that the customers needs would be engineered into the product
D-1.2	Deliver system design drawings (Task 8) By requiring a complete system design this deliverable assures smooth deployment of systems employing the SunSine300.
D-1.3	Deliver documentation of Rev 3 MSI (Task 2) A complete BOM insures that price estimates are accurate and is necessary when going into production. Performance documentation provides confirmation that engineering specs are being met.
D-1.4	Deliver design documentation of enclosure (Task 3) Provides confirmation of completion of design without waiting for

	fabrication lead times.
D-1.5	Deliver PV Module rating documentation (Task 5) This provides verification of target performance.
D-1.6	Deliver photographs of AC module prototypes (Task 6) Provides NREL with documentation
D-1.7	Deliver prototype AC modules to NREL and SNL (Tasks 6,7 & 8) This provides NREL and Sandia with the opportunity to test the products. This is a big help to AT since both Sandia and NREL have sophisticated test equipment that can provide AT with test information that might not otherwise be available.
D-1.8	Deliver FCC test result summary (Task 7) FCC verification is highly desirable for this type of device if it is to be mounted on residences. It assures that there will be no interference with receivers such as TV, radio or cordless phones.
D-1.9	Deliver preliminary UL verification of test (Task 4) UL listing is a long and complex process. This task demonstrates significant progress towards the ultimate goal of a UL listed product.

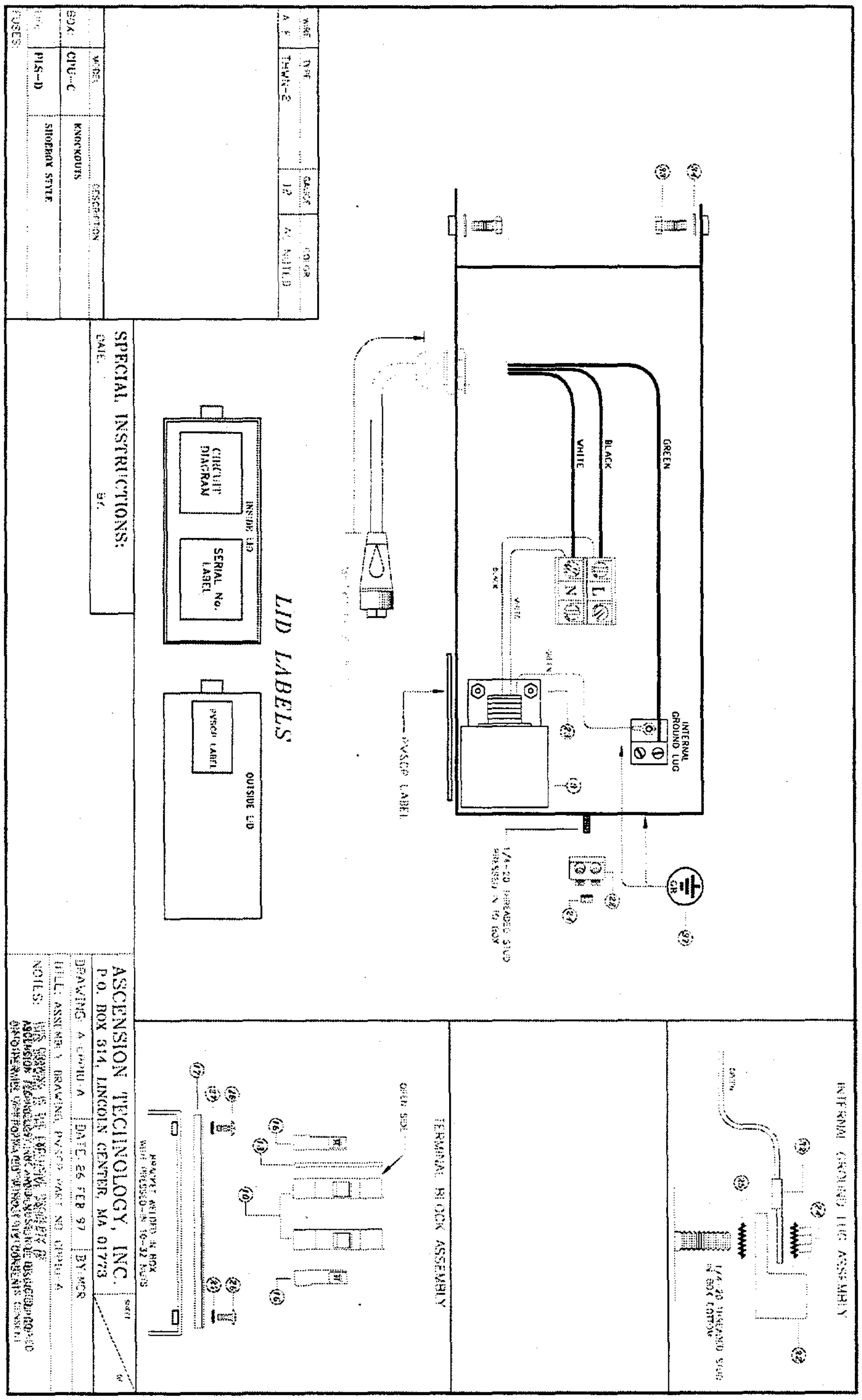
APPENDIX A

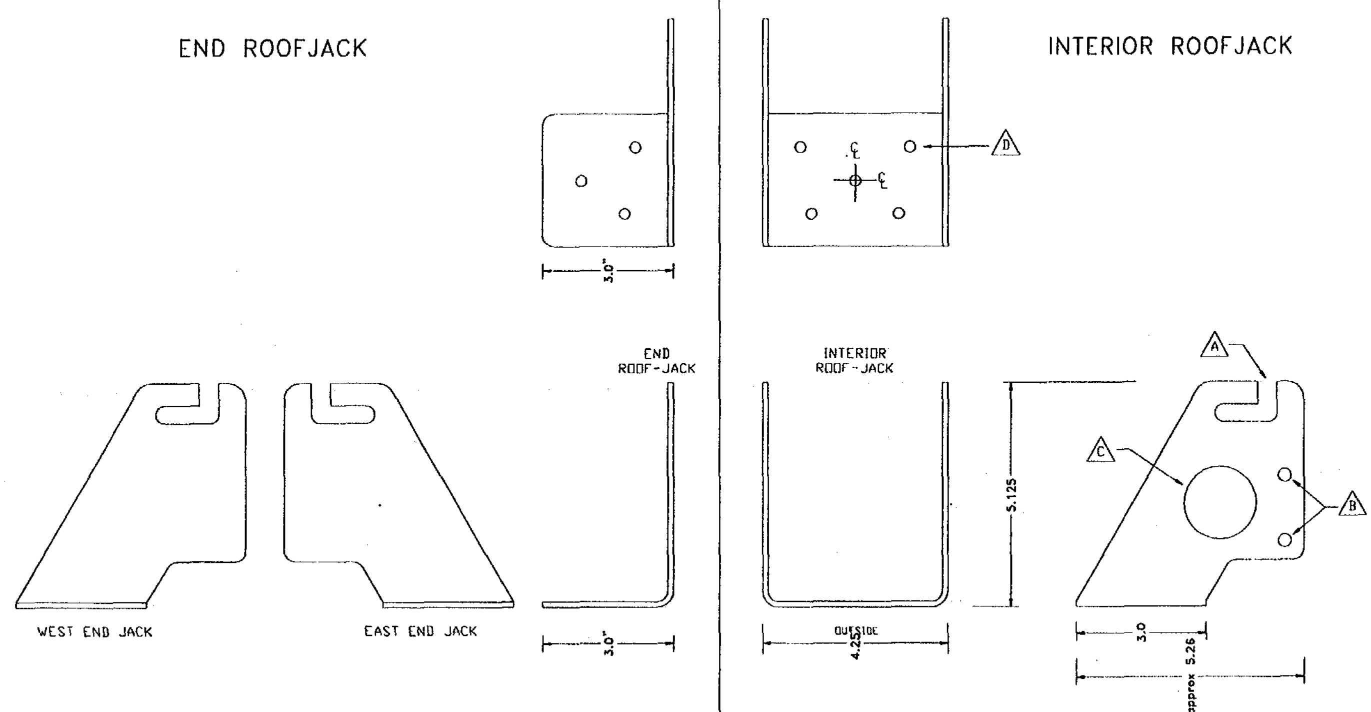
COSPONSORING UTILITIES

1	Arizona Public Service Company
2	Atlantic City Electric
3	Central and SouthWest Services
4	City of Austin Electric Department
5	ConEdison of New York
6	Delmarva Power and Light
7	Kansas City Power and Light
8	Long Island Lighting Company
9	Nevada Power Corp.
10	New England Electric
11	New York Power Authority
12	New York State Electric and Gas
13	Northern States Power
14	Pacific Gas and Electric Company
15	Public Service Company of Colorado
16	Sacramento Municipal Utility District
17	Salt River Project
18	Southern Company Services
19	Wisconsin Public Service Company

APPENDIX B

COMPONENT DRAWINGS





MATERIAL: ALUMINUM
FINISH: MILL FINISH

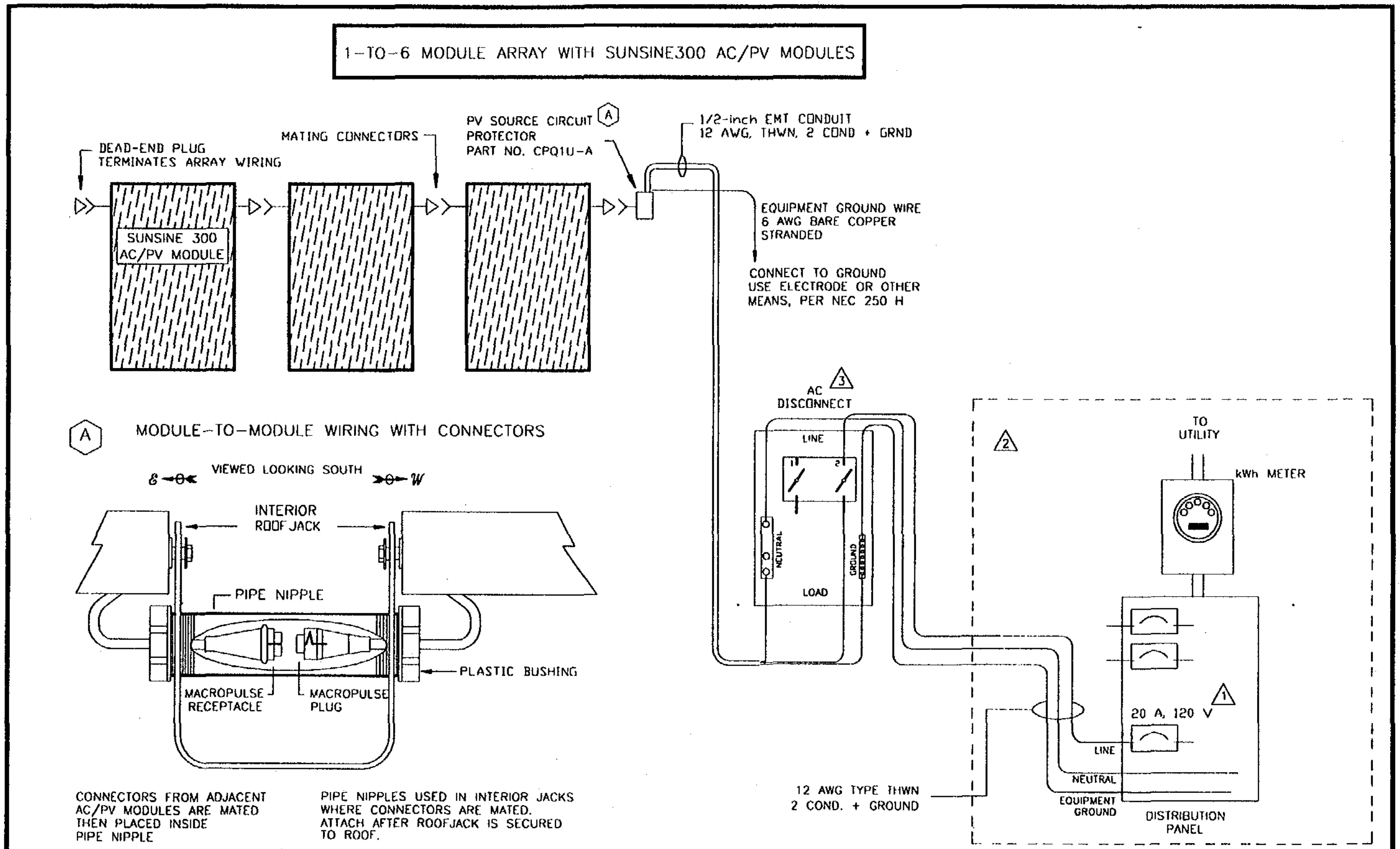
A. SLOT IS FOR MATING WITH MOUNTING PIN ASSEMBLIES

B. HOLES USED FOR ATTACHMENT OF PV SOURCE CIRCUIT PROTECTOR SEE DRAWING I-CPURJ-D

C. HOLES USED FOR ATTACHMENT OF PIPE NIPPLE 1.25" X 5", WITH PLASTIC BUSHINGS

D. HOLES USED FOR SECURING ROOFJACK TO ROOF SURFACE TYPICAL. #12 X 2.25" ROOF INSTALLATION SCREW

ASCENSION TECHNOLOGY, INC. P.O. BOX 314, LINCOLN CENTER, MA 01773	SHEET OF	
DRAWING: I-RJAX-F	DATE: 14 JAN 97	BY: MCR
TITLE: PITCHED-ROOF ROOFJACKS, REV. F		



SYSTEM RATINGS

NUMBER OF AC MODULES	MAX AC CURRENT	POWER (Wac) PTC	STC	MAX
1	2.5	240	264	300
2	5	480	528	600
3	7.5	720	792	900
4	10	960	1,056	1,200
5	12.5	1,200	1,320	1,500
6	15	1,440	1,584	1,800

1. PV SYSTEM CIRCUIT BREAKER
LOCATE THE CIRCUIT BREAKER FOR THE PV SYSTEM AT THE POSITION FARTHEST FROM THE MAIN BREAKER IN THE DISTRIBUTION PANEL (I.E., AT THE BOTTOM)

2. A NET-METERED CUSTOMER-SIDE INTERCONNECTION IS SHOWN.
OTHER INTERCONNECTION METHODS MAY BE USED.

3. OPTIONAL AC DISCONNECT SWITCH
UNFUSED, NEMA 3R, 240 Vac
NEUTRAL NOT GROUNDED IN BOX

ASCENSION TECHNOLOGY, INC.
P.O. BOX 314, LINCOLN CENTER, MA 01773

QUANTITY

DRAWING: W-3SS1-A | DATE: 3 MAR 97 | BY: MCR

TITLE: WIRING DIAGRAM: 1-6 MODULES AT 120 VAC