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Development of Standardized, Low-Cost AC PV Systems

Phase I Annual Report, 7 September 1995 - 7 November 1996

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PHASE 1 ANNUAL REPORT

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Subcontract Title:	**Development of Standardized, Low-cost AC PV Systems**
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1.0 EXECUTIVE SUMMARY

The objectives of this two-year program are to improve the reliability and safety and reduce the cost of installed grid-connected PV systems by creating standardized, pre-engineered components and an enhanced, low-cost, 250-Watt micro inverter. These advances will be combined with the new, large area Solarex MSX-240 PV module resulting in standard, modular AC PV "building blocks" used to create utility-interactive PV systems as small as one module to many thousands of modules to suit virtually any application. AC PV building blocks will be developed to meet the requirements of the U.S., Japanese and European markets.

Accomplishments: During the first year Phase 1 effort, the following work was accomplished:

- Completed a system-level review of present practice in PV systems design and components with input from utilities active in PV.
- Completed a detailed review of building code requirements on PV module mounting systems and developed generic design criteria to address these requirements.
- Completed design of standardized PV system mounting systems for sloped roof, flat roof and ground mounting.
- Built and evaluated prototypes of the three mounting systems.
- Defined and selected a hard-wiring system and a quick-connect system for electrical connection of the AC modules.
- Successfully completed mechanical loading tests on a frameless MSX-240 module.
- Completed design and prototyping of the advanced digital micro inverter
- Completed initial testing and qualification of the advanced digital inverter
- Completed an initial production run of enhanced digital inverters
- Completed initial discussions with UL for UL listing of the digital inverter
- Completed discussions with UL and agreed on test program for UL listing of MSX-240 module in the mounting systems designed for this program.
- Developed a qualification test sequence for the micro inverter.
- Completed design and prototyping of advanced digital inverters for Europe and Japan
- Delivered two AC PV modules, each comprised of a Solarex 240 Wp large-area PV module and an AESI digital micro inverter for testing and evaluation: 1 to NREL and 1 to Sandia.

Significance of Results: The work undertaken in this program has the potential to completely change the way utility-interactive PV systems are sized, priced and installed. The AC module will become the first photovoltaic power "building product", as it can be marketed as a complete, packaged solution for the emerging residential rooftop and commercial demand-side management / supply markets. Integral two-way communications and data acquisition are standard features on each AC module.

AC modules can be sold with frames to be mounted on conventional support structures or, they can be sold without frames as glass laminates for direct building integration where the PV module displaces conventional building materials such as architectural glass in commercial buildings. With the cost of the displaced architectural glass and the labor to install it credited toward the cost of the PV system, building-integrated PV becomes very attractive. This is especially true with the AC module's ease of installation.

In addition, AC modules allow significant flexibility in system sizing. Systems as small as one module can be fielded and can then be added to in increments of one module. Orientation and shading of the array is not as much of a concern as with conventional systems and, since every AC module has its own maximum power point tracker, the mismatch losses common to series DC strings of PV modules are eliminated.

With all these advantages, the enhanced digital micro inverter and the resulting AC photovoltaic modules and standardized systems developed under this program have the potential to become universal building blocks for use in all utility-interactive PV systems.

2.0 INTRODUCTION

In 1990, the U.S. Department of Energy initiated the Photovoltaic Manufacturing Technology (PVMaT) program to help the U.S. photovoltaic (PV) industry extend its world leadership role in manufacturing and in developing commercial PV modules and systems. The program is designed to help the industry improve manufacturing processes, accelerate manufacturing cost reductions for PV modules, improve commercial product performance, and lay the groundwork for substantially scaling up the capacity of U.S.-based PV manufacturing plants.

PVMaT is a four-phase research and development partnership between the U.S. federal government (through the Department of Energy) and members of the U.S. PV industry. This subcontract was let under Phase 4-A1 which deals with Balance-of-System issues.

Solar Design Associates, Inc.(SDA), an architectural and engineering firm specializing in PV systems engineering and product development, is the Prime Contractor. Key subcontractors are Solarex, a business unit of Amoco/Enron Solar and the largest US-owned manufacturer of photovoltaics and, Advanced Energy Systems, Inc. (AESI), designers and manufacturers of power electronics for the renewable energy industry.

This report of Phase 1 activities is organized by the individual tasks which made up the Phase 1 Statement of Work. These key tasks are as follows:

Task 1: A System Level Review of PV Systems Design and Components
Task 2: Innovative Mounting Systems
Task 3: Enhanced Digital Inverter
Task 4: Standardized, Pre-manufactured Wiring Systems
Task 5: Standardized, Modular System Design
Task 6: Digital Inverter for Japan
Task 7: Digital Inverter for Europe

3.0 TECHNICAL STATUS

3.1 Task 1: A System Level Review of PV Systems Design and Components

At the start of the Phase 1 effort, the past and present PV systems design and installation practices were systematically examined with the goal of defining cheaper, more manufacturable products using simpler, standardized designs and, ultimately, to deliver lower cost AC PV systems to the customer.

In addition, a detailed review of building code requirements on PV module mounting systems for sloped and flat roofs was performed and generic design criteria was developed to address these requirements

Copies of the results of the work were delivered to NREL. SDA and Solarex staff incorporated the findings into the development plan for the subsequent tasks.

3.2 Task 2: Innovative Mounting Systems

In Task 2 SDA and Solarex developed low-cost methods of array mounting and structural support for sloped and flat roofs of residential and commercial buildings as well as ground-mounted arrays using pre-engineered, standardized components and large-area Solarex MSX-240 modules.

SDA and Solarex engineers met several times early in the program to discuss in detail the many array-mounting methods with which we are familiar. Perceived advantages and disadvantages of each method were identified, and cost estimates were generated for installed system cost using each method.

Sloped Roofs: Initial discussions concentrated on mounting methods for sloped roof installations. The following methods were evaluated:

- Z-brackets with framed modules.
- The Solarex "Ready Mount" frame which is a custom aluminum extrusion in a "Z" section which supports the long sides of the 240 Wp module
- Aluminum sections with unframed laminates and low cost foot.
- Steel channel with roof jacks and unframed laminates.

Most of the approaches considered use unframed laminates, but there was concern about the potential for damage during handling and shipping of laminates. Solarex is confident that breakage in transit can be held to acceptably low levels, providing adequate shipping containers are specified. However, the cost of the shipping container may offset the reduced cost of the frameless modules. This issue was considered in the final selection of a mounting method.

Our initial estimates indicate that one of the key drivers of total installed cost is the labor required for mounting the array. This is also the aspect of the different methods which we knew the least about. Therefore, Solarex personnel performed the installation of a PV array using each mounting method and videotaped the process for further analysis. The results are summarized below:

- Z-brackets with framed modules. This method required very little time on the roof. However, the brackets are definitely not as rigid as the other mounting methods.
- Ready Mount frame. The ready mount results in a very heavy system that is not easy to lift into place.

- Steel channel with roof jacks and unframed laminates. The roof jacks require too much time on the roof for exact placement of the bracket.
- Aluminum sections with unframed laminates and low-cost feet. This system was easy to install and thus was projected to have the lowest cost.

A system with aluminum sections with unframed laminates and low-cost feet was selected for development. Drawings of the mounting system are one of the Phase 1 deliverables provided to NREL.

A 1 kW prototype system was assembled and installed on a sloped roof structure at Solarex built to mimic a residential roof with standard asphalt roof shingles. The array consisted of 12 panels, each made up of four MST-22ES modules, attached to aluminum struts with RTV. These were mounted to the roof using foot brackets and lag screws. This installation is presently undergoing testing and evaluation. Photographs of this test installation are part of the Phase 1 deliverables provided to NREL.

Flat Roofs: For the flat roof system we have selected the roof pan concept using a tray of galvanized sheet metal filled with crushed stone as ballast.. This mounting approach works well, but is considerably more expensive than the other two types of array mounting. Drawings of the concept are part of the Phase 1 deliverables provided to NREL.

A four MSX-240 module flat roof demonstration system was installed on the west wing roof of Solarex's Frederick Technology Center. That system was grounded through the metal support structure per the NEC code. AC wiring has been provided to the array. Photographs of this test installation are part of the Phase 1 deliverables provided to NREL.

Ground-mount: A review of ground mounted support structures was completed. We have proposed the use of unframed laminates with the same aluminum sections proposed for the sloped roof system. The major difference involves the method of support for this structure. Most of the systems we have seen require too much site preparation, use too much material (typically poured concrete footings) or have high installation costs such as buried telephone poles or screwed in anchors.

Rather than bury something in the ground, we are proposing to provide sufficient weight in ballast for the array to resist sliding and overturning wind forces. We selected a ground-mounted system that uses old tires filled with concrete at the site. Old tires are free (or sometimes you get paid to use them in an environmentally sound application) and the concrete cost about $3.00 per tire. The module height is adjustable by sliding the laminate along the aluminum sections. The angle is adjustable by varying the length and angle of the support legs. Drawings of this system are part of the Phase 1 deliverables provided to NREL.

Four MSX-240 frameless modules were installed at Solarex in a cement-filled-tire ground-mount configuration. Installation went quickly with each module requiring less than 10 minutes to align and level. The most time consuming part of the installation was the mixing and pouring of cement which was done by hand for this prototype array. Of course, for a large system, a ready-mix cement truck would be used to pour concrete into each tire. This particular array used simple aluminum channel which was simply buried into the wet cement at four points.

It was found that 13" tires gave spacing between modules of approximately 1 1/2" to 2" . When a combination of 14" and 15" tires were used, the spacing increased to 4" to 5". Also, it was noted that the 14" and 15" tires took approximately 50% more concrete to fill. Average hold down weight per array amounted to approximately 880 lb. or 220 lb./tire. Photographs of this test installation are part of the Phase 1 deliverables provided to NREL.

Static load testing of the ground-mount system was completed. The module successfully met the requirements of IEEE 1262 at 50 psf. We tried to continue the test up to the optional snow load level of 113 psf specified in IEC 1215. The module broke at 107 psf. There are 2 issues with this failure.

- The weight used in this test was sand bags. These do not provide perfectly uniform loading. We have since switched to water loading to assure uniformity.
- The aluminum sections ended about a foot short of the one end. The module first broke at the points where the beams ended.

A mechanical load test fixture was prepared for the MSX-240 using water as the weight. We then performed mechanical load tests on an MSX-240 in this fixture. The module was mounted using the same beam configuration as used on the ground-mounted tire array. It successfully passed the IEEE 1262 mechanical load test at 50 psf and the IEC 1215 snow load of 113 psf. Photographs of this test are part of the Phase 1 deliverables provided to NREL.

All three prototype array mounting systems have been completed and are being evaluated for performance. This evaluation will continue during Phase 2 of the program.

3.3 Task 3: Enhanced Digital Inverter

In Task 3, an advanced digital micro inverter was developed using the SDA analog micro inverter developed under contract for the DOE's Building Opportunities for Photovoltaics in the US (PV:Bonus) program as a basis for the new design. Solarex supported the digital development effort by reviewing the performance of the early analog inverter, and performing qualification, environmental and performance tests on the new digital version. Input from this testing was used in the development of the final digital design. The new digital inverter design improves reliability while reducing manufacturing costs by combining a number of separate analog control functions into one digital processor which reduces parts count and PC board real estate.

The first part of this task involved testing the analog micro inverters on PV modules to study the inverter performance and reliability. We utilized the existing Kawneer PowerWall test structure at Solarex and the new ground mounted tire array, built for the PVMaT program and described under Task 2. Six of the early analog inverters were installed on the MSX-240 modules in the PowerWall demonstration structure at the Frederick facility. Data from these test was used to prepare the paper entitled "The AC Photovoltaic Module" presented at the *25th IEEE Photovoltaic Specialist Conference* held in Washington, DC in May, 1996.

During testing and evaluation of the analog inverters, it was discovered that the optoisolators caused an instability in the output unfolder. Noise on the line would cause spikes in the optoisolator inputs which would erroneously turn on some drivers. This would result in one or more of the output unfolder FETs and/or the AC fuses burning out. The optoisolators were replaced with another form of isolation in the digital design, and no further problems have been experienced.

Digital MI Software development: Phase tracking was added to the digital inverter's operating software to improve the inverter's tolerance of glitches in the AC grid caused by inductive spikes to the line. Essentially, this new software uses a digital phase-locked loop to lock onto the line frequency. This involves a tradeoff between immunity to line noise and responsiveness to variable frequency. If the AC module is run off of relatively small (stand-alone) generators, it may be necessary to change the lowpass filtering parameters to allow for drift in the line frequency. Frequency drift is normally not a problem with grid operation.

Testing was done with a line noise generator to simulate noisy AC and the new design has been determined to be more robust. A phase jitter of about 50 uS has also been eliminated. Short-term dropouts, as observed from frequent large motor starts in a noisy industrial environment, have been reduced from 10's per hour to only a few per day.

Anti-islanding has been tested with resistive, capacitive, rectifier-type (that only draws power at the peak voltage), and induction motor loads, all matched to power input of the inverter, to attempt to cause islanding. Matching the load guarantees that the output voltage will not go out of bounds, and is considered the worst case for the islanding test. No islanding was experienced. The inverter can be set, via parameter, to drift up or down in the event of a loss-of-utility to avoid an islanding condition. With the dropout set at +/- 3 Hz, the worst case experienced was 10 second islanding. The inverter will shut down in one-half second or less on a load with a bad power factor or a capacitive load, because the voltage wave shape becomes grossly distorted.

The anti-islanding method is now selectable in EPROM. The default is to drift up, which gives a cleaner waveform. Originally, we had decided to drift down in frequency, because of the theory that some perfectly-matched inductive loads might tend to push the frequency down and therefore cause a situation where the inverter and load balance, and islanding could occur. At this point, it is an unproved theory, and we have not been able to cause these conditions in the lab. If, for regulatory reasons, it becomes a requirement, we can select the other option, at a small penalty in waveform quality.

Digital MI design: The analog inverter's control section used a standard 16 MHz 8051-derivative micro-controller, running at about 1 MIP (million instructions per second). About 90% of the processing power was used for background tasks (temperature, input voltage and frequency checks, some anti-islanding checks, waveform correction, data acquisition and serial communications, etc.), while the rest of the processing (about 0.1 MIP) was used for control of the waveform and most of the anti-islanding control. With this amount of processing power, the controller could update the waveform about once per second. In the digital inverter, the controller was replaced with a much faster model, running at about 6 MIPs. The background processing remained the same, but the processing power available for waveform control increased to about 5 MIPs, a 50-fold increase. This allows about 6 waveform updates per second, resulting in much better waveform quality and quicker convergence after start-up.

EMI noise reduction - Testing revealed that most of the noise injected onto the line was radiated from the digital section to the power wires inside the case. To remedy this situation, filters were added near the output connectors and the area will be isolated with a metal shield.

Case design - A new case was designed for the digital inverter which consists of 4 components - an aluminum extrusion, clips to hold the FETs, an insulator between the FETs and the case, and a cover. A totally new extrusion was designed for the case. The new extrusion makes the product look very polished and professional, and has performed well in dissipating heat. The original clips were a custom design, and did not hold the FETs tightly enough against the extrusion. After some experimentation, we determined that a mica insulator and standard (hardware store) paint can cover clips gave us the best transfer of heat. Using the mica/paint clip combination also reduced the mounting cost from about $2.50 to $ 0.25 per case. The new case also has 20 fewer screws and will make assembly much simpler. This reduced the case cost by 35%. The PC board size in the digital inverter was also reduced, which reduced the etch cost by about 30%. Separating the 4-layer control section into a daughterboard will further reduce the etch cost. The digital design effort also reduced the component count significantly, resulting in an additional cost savings of about 20-25%. Better sourcing and higher volumes will substantially reduce the cost of the magnetics, in some cases reducing the costs of individual parts by as much as 70%.

Initial prototype testing: In August, four initial pre-production prototype digital inverters were installed on the ground-mounted tire array at Solarex. When first installed they worked fine, but by the end of September all four inverters on the ground mounted system had failed. This was a very wet period and we believe that water leaked into each unit. They were sent back for evaluation. Upon examination, it was discovered that the inverters failed because of moisture damage. Initially, a treated paper insulator was inserted between the main board and the case. This paper insulator soaked up moisture, buckled, and shorted various components, usually blowing the fuses and sometimes also the unfolder FETs. The insulator was replaced with FR4 material. In addition, new conformal coating and potting compounds are being investigated which promise to further protect the inverter from environmental failures.

Further, a new layout of the digital inverter's PC board will be undertaken at the beginning of Phase 2. The control section will be separated onto a daughterboard. The main board will contain all through-hole components, and can be double sided. All of the surface mount components will be on the daughter board, which can be 4 or 6 layers. This reduces the cost of the etches by about 30%. It also allows the machining of the cut-off through-hole leads for better adhesion of the conformal coating. The UL-required changes and new EMI filtering will be added to this layout. Less expensive components will be evaluated.

Sandia Design Assessment: An advocate at DOE HQ suggested to SDA that the experience at Sandia Laboratories (SNL) might well provide significant assistance in the complex and challenging effort of developing a reliable 'bullet-proof', low-cost micro inverter. In July (1996) Sandia National Laboratories hosted a group from SDA and AESI at SNL with the purpose of reviewing the micro inverter design and proposing ways that the talents and resources within the Sandia community could be made available to help accelerate the digital micro inverter development. Useful information was gleaned from the initial visit and it was proposed that Sandia would review their capabilities and provide SDA with a proposal as to how they might help move the MI design forward. While it was recognized that there were many talents and resources at Sandia, the SNL PV program and the laboratory in general were under budget pressure and there was concern among the PVMaT program representatives as to how we could access the Sandia talent and how their high overheads and charge rates could be covered. At the end of our Phase 1 effort, these issues were still being investigated.

Qualification testing: Work under this task also involves the development of a qualification test sequence for the digital micro inverters. Since the micro inverter must perform while attached to the PV module, it must be capable of withstanding environmental stresses similar to those that the module is subject to. As a start, it was decided to expose the inverter to thermal cycling, damp heat and long-term thermal stress.

The first environmental test specified was the thermal cycle test. In IEEE 1262 the modules are exposed to 200 cycles from -40°C to + 90°C. To simulate inverter operations, we designed the test to have AC input at all times, but no DC input during the low temperature excursion. As the chamber heats up to room temperature, the DC voltage is switched on. It remains on until the temperature drops below room temperature. The output of the inverter is monitored throughout the test.

We began by thermal cycling two of the prototype inverters. As the temperature approached the upper limit, the inverter automatically shut off as it should at these high temperatures. However, when the temperature dropped below the set point, the inverters did not turn back on as they should. The only way to get the inverters back on was to shut off the DC input. This is not an acceptable operating mode, since it means that once shut off by high temperature, the inverters will not turn on until the next day, sacrificing late afternoon energy. It was determined that there was a software error that was easily corrected. Subsequent testing of inverters did not exhibit this problem.

The two inverters completed 200 thermal cycles and were still performing well. It was decided to continue the thermal cycling tests beyond the normal 200 cycles. Soon after 200 cycles, the inverters began to buzz when energized. After 300 cycles, both units failed to ramp up in output power as the DC increases and randomly shut down in apparent attempts to re-start. The data communications could still talk to both units. These inverters were sent back to AESI for failure analysis.

Two prototype inverters were subjected to the damp heat test (1000 hours at 85∞ C, 85% RH). Both units failed during the test. Neither had any output nor could either communicate with the data acquisition. These units were also sent back for failure analysis.

During initial testing of the digital prototype, there were several failures of the main rectifier diode. Investigation of the failure revealed high frequency switching noise was exceeding the maximum reverse voltage of the diode. The 'spike killer' was not performing as expected, and more turns were added to the coil. With the new spike killer design, the reverse voltage has been reduced from a maximum of about 670V to about 390V.

All the information from these early qualification test runs was used to refine the digital unit prior to delivering the two AC modules (one NREL and one to SNL) at the end of Phase 1. Testing and refinement of the new digital design will continue during Phase 2.

UL listing requirements - After more than 6 months of review, UL responded with a list of requirements necessary to obtain UL listing of the inverter. The major change is that AC and DC wiring can not be in the same conduit. Since the Solarex panel can be either framed or have 2 rails, the space allowed forces the new design to have a nipple (or connector) on each end of the inverter. Because the board layout must change considerably to accommodate this, there is a risk that there may be some noise problems inadvertently introduced that will require a complete new board design. The other changes are fairly minor, including the method of grounding the case, and some component issues. UL was also asked to provide information about meeting the local regulatory requirements in Japan and Europe, but the UL report contained little specific information. A host of specifications have since been ordered, and UL has been requested to supply more information. As part of our Phase 2 effort, we will obtain UL listing of the US digital micro inverter.

3.4 Task 4: Standardized, Pre-manufactured Wiring Systems

In Task 4 Solarex and SDA were to define and develop innovative, low-cost methods of module-to-module electrical interconnection, array wiring, string interconnection, lightning protection and array grounding for systems on residential and commercial buildings as well as ground-mounted arrays through the use of pre-engineered, standardized components.

A conceptual design was developed for a wiring harness capable of connecting up to four modules in parallel, and a circuit combiner capable of connecting two groups of four modules. The output of the combiner would be compatible with connection to a standard 20 amp AC circuit breaker. The goal was to identify UL listed connectors suitable for use in such a wiring harness and combiner box.

During the course of the program a number of connectors were evaluated including:

- Turck
- Methode
- Amphenol
- Clipper
- Bryant
- Brad-Harrison

Turck connectors were used on the ground-mounted tire array. Methode connectors were used on the flat-roof system. The sloped-roof system was hard-wired without quick-disconnects. All three systems appear to be acceptable in terms of technical performance and for meeting safety codes.. We selected the Turck system as our baseline because it was readily available. All of the quick connect systems are more expensive than our original program goal. However, for small systems with only a few modules, the ease of installation may overcome the higher component cost. Drawings of this component are part of the Phase 1 deliverables provided to NREL.

The original wiring plan called for the AC output wiring of the inverter to come back into the Solarex module junction box through the same hole that the DC input wiring enters through. For this case we proposed the use of a Turck connector system that attached through one of the knock-outs in the J-box. However, during the UL review of the inverter, UL objected to this design, stating that the DC and AC wiring could not go through the same conduit or raceway. Therefore, the inverter will have to be redesigned with an AC connector on the opposite end. AESI has been provided with a list of possible connectors for this application. Options evaluated include:

- Lemo
- Brad-Harrison
- Lumberg

The Lumberg connectors are about one-third the price of the Turck connectors that were originally selected and are essentially the same functionally. The next step will be to qualify the Lumberg connectors.

A second option for the inverter wiring is to provide a three-wire AC output through a cable gland. This would seal the inverter from moisture and provide the user with three AC wires that can be connected to the systems wiring in a junction box. During their initial work in Phase 2, AESI must decide which of these termination systems to use in the final unit submitted for UL listing.

3.5 Task 5: Standardized, Modular System Design

In Task 5 Solarex was to work with SDA to combine the results of Tasks 1-4 to create standardized, modular AC PV systems which can be packaged as kits by Solarex. Solarex worked with SDA to define the "building blocks" for these kits, incorporating comments from potential customer and developing prototype systems.

One of the first steps in the creation of a standardized, modular system is to obtain UL Listing for the major building blocks. We have completed discussions with UL and have agreement on which tests from UL 1703 must be completed in order for UL to certify the MSX-240 in the frameless mounting system.

The three prototype AC module arrays fielded at Solarex during Phase 1, (sloped-roof, flat-roof and ground-mount) are our candidates for the standardized AC PV systems. Once the testing results are obtained from UL we will use this input to further refine the design and specification of the standardized, modular AC PV systems during Phase 2.

3.6. Task 6: Digital Inverter for Japan

The Japanese prototype digital micro inverter was tested in November using the US-version MI hardware as a test bed with software changes. The line voltage in Japan is close enough to the US standard (110 vs. 120) that the same hardware could be used. The software was modified to operate at 50 Hz and this has been incorporated into the main software as a programmable option. Development of the digital inverter for the Japanese market is scheduled to continue during Phase 2 under Task 10.

3.7. Task 7: Digital Inverter for Europe

The European digital prototype was tested in late December using a modified version of the US-MI. The control section is essentially the same, but a dozen parts needed to be modified to operate at the higher line voltage. Some parts were more expensive because of the higher voltage, and some parts were less expensive because of lower current, resulting in a design with approximately the same cost as the US version. Development of the digital inverter for the European market is scheduled to continue during Phase 2 under Task 11.

4.0 PHASE 1 DELIVERABLES

D1.1: A summary of the system-level review of PV system design
D1.2: Drawings and materials lists for prototype mounting hardware
D1.3: Drawings and/or photographs of prototype wiring hardware
D1.4: Two pre-production enhanced digital micro inverters with PV modules
D1.5: Updated drawings of mounting hardware
D1.6: Updated drawings and/or photographs of wiring hardware
D1.7: Updated drawings and/or photographs of prototype standardized mounting systems

5.0 PLANS FOR PHASE 2

During the second year of this program the work will include the following key tasks:

- Continue to refine the design of the digital inverter and obtain UL listing for the inverter and the AC module, both as separate components and as an integrated assembly.
- Complete qualification testing of the new digital inverters at Solarex and elsewhere in both accelerated environmental tests and outdoors on MSX-240 modules.
- Complete UL listing of the MSX-240 frameless module mounted on beams as developed for this PVMaT program.
- Continue to monitor the 3 prototype arrays at Solarex and solicit potential customer feedback.
- Identify and qualify a quick connect system for the micro inverter AC wiring.
- Commercialize the AC module.
- Complete development and testing of the standardized AC module systems designs and obtain UL listing of the components and assembled systems.
- Complete development work on the Japanese and European digital inverters.
- Fabricate and test pre-production inverters for the Japanese and European markets.

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13. ABSTRACT (Maximum 200 words)

The following work was accomplished by Solar Design Associates, Inc., during the first-year Phase I of this subcontract. Researchers completed a system-level review of present practice in PV systems design and components with input from utilities active in PV; completed a detailed review of building-code requirements on PV module mounting systems and developed generic design criteria to address these requirements; completed design of standardized PV system mounting systems for sloped roof, flat roof, and ground mounting; built and evaluated prototypes of the three mounting systems; defined and selected a hard-wiring system and a quick-connect system for the AC module electrical connection; successfully completed mechanical loading tests on a frameless Solarex MSX-240 module; completed the advanced digital micro-inverter design and prototyping; completed the advanced digital micro-inverter initial testing and qualification; completed an initial production run of enhanced digital micro-inverters; completed initial discussions with Underwood Laboratories (UL) for UL listing of the digital micro-inverter; completed discussions with UL and agreed on test program for UL listing of MSX-240 module in the mounting systems designed for this program; developed a qualification test sequence for the advanced digital micro-inverter; completed the design and prototyping of advanced digital micro-inverters for Europe and Japan; delivered two AC PV modules, each comprising a Solarex 240-Wp, large-area PV module and an Advanced Energy Systems, Inc., digital micro-inverter for testing and evaluation: one to NREL and one to Sandia.

14. SUBJECT TERMS

photovoltaics ; Photovoltaics Manufacturing Technology Program ; PVMaT ; grid-connected PV systems ; AC PV systems ; utility-interactive PV systems ; digital micro-inverter

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