SUITLAND FEDERAL CENTER'S 100 KW AMORPHOUS PV INSTALLATION: THIN FILM TECHNOLOGY IN A UTILITY-SCALE APPLICATION

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ABSTRACT

Thin film photovoltaic modules have long held out the hope of a lower cost per Watt. As new thin film products come to the PV module marketplace, this hope is becoming a reality. The challenge that these products present and the obstacle to their widespread adoption in large, utility-scale applications, is their relatively low efficiency, or low power density, when compared with crystalline technology, and their resultant higher cost of installation. Low power density results in a greater number of electrical connections, a greater mass of panelized product, and a larger number of balance of system components for every peak Watt installed. Appropriate design and installation approaches, together with manufacturing advances, offer solutions for these issues. Using the recently completed Suitland Federal Center 100 kW amorphous silicon thin film array as an example, we will identify approaches that worked well in this installation and ideas that may be applied to any large-scale installation that can lead to lower construction costs.

1. HISTORY

In the summer of 2000, Pepco Energy Services and Applied Power Corporation, under contract to the General Services Administration (GSA), installed a 100 kilowatt photovoltaic system in Suitland, Maryland. The Suitland PV system is comprised of 2800, 43 Watt BP Solar Millennia™ modules with Integra™ frames. It is a ground-mounted installation, at a fixed tilt angle of 30 degrees, supported by a steel structure. The system is located at the Federal Center, approximately five miles south east of the District of Columbia. The Federal Center houses the National Records Center, the headquarters of the Census Bureau, offices of the National Oceanic and Atmospheric Administration (NOAA) and a branch of Naval Intelligence. The array is sited in a decommissioned cooling pond that has been filled with soil. The system was commissioned in mid-September of 2000.

2. THE DESIGN CHALLENGE

Thin film cell technology has been available for some time. However, it has been only recently that commercial modules have been produced in large quantities. PV module manufacturers are bringing promising new thin film products to the marketplace with higher efficiencies, better quality control and lower costs per watt. The fundamental challenge associated with thin film technology in large, utility-scale systems is their relatively low efficiency when compared with other types of PV such as single crystal and polycrystalline products. Viewed solely from an installer perspective, the figures of merit are Watts per kilogram (W/kg) and Watts per meter squared (W/m^2). For the Suitland project, BP Solar Millennia modules with Integra frames were chosen. These modules have an efficiency of 5.4% and provide 54 Watts/m^2 (All references to module efficiency and power ratings are at standard test conditions). In comparison, single or polycrystalline modules are typically 110 – 135 W/m^2. A single panel of five Millennia modules --the fundamental building block for the Suitland system-- weighs 91 kg and is approximately 1.2 m long and 3.4 m wide. This panel assembly is a four-man lift and is extremely awkward to handle. In terms of weight, a standard construction module (glass/tedlar) provides approximately 9.5 W/kg, and a double glass module is approximately 6.0 W/kg. The Millennia module is rated at approximately 2.5 W/kg. What this means, from an installer's perspective, is that thin film modules present a much greater materials handling task than a crystalline module.

Just as with issues of weight and size, the number of parts required to assemble a thin film system is much greater than with other systems. The number of electrical connections for each Watt installed is much greater with a thin film system than with competing technologies. For the Suitland system there are over 4000 current carrying connections in the panels alone, not counting any of the connections to the combiner boxes, fuse boxes, DC disconnects or inverter. In addition there are another 4480 wires that require terminating caps. This compares with less than 400 current carrying connections in a similar sized system using a large area polycrystalline module.

3. THE SUITLAND 100 KW DESIGN

From the beginning, this project was intended as a demonstration that a large-scale PV system could be implemented using a currently available commercial amorphous silicon product. Critical enabling features of this design approach were (1) the adoption of existing building trade practices, (2) the use of existing, standard building materials, (3) careful planning of the flow of work and materials, and of quality control procedures, and (4) more sophisticated product integration by the module manufacturer. The Suitland array structure adopted a successful existing ground mount design developed by Applied Power Corporation on previous projects. A completely new five-module panel design for the 43 Watt Millennia modules was developed, together with a new system of outdoor rated interconnection cables. The Integra frame of the Millennia module serves as both mounting system and conductor raceway. To form the mechanical unit for the panel, five modules were mounted to a pair of 3.4 m galvanized steel rails, using a standard component utilized in steel framed roofs as the rail material. The rails were cut to length and pre-drilled at the manufacturer to the hole spacing dimensions required for the panels, although some on-site machining was still required. When compared with rails that would have been custom fabricated for a system of this size, this off-the-shelf solution represented a significant cost savings in materials.

The Millennia modules include output cables with AMP connectors. These connectors are designed for photovoltaic applications and have all live parts guarded on both male and female parts. For repetitive panel-to-panel wiring, Applied Power designed and manufactured a low-cost, UV rated cable assembly with integral mounting clip and mating AMP connectors. This wiring assembly provided a fast, reliable, and NEC compliant method of making the more than 1,100 panel-to-panel field interconnections required for the system. This seemingly minor detail was a key design feature in reducing the labor cost associated with the field wiring of the array and reduced the quality control requirements to manageable levels.

A major challenge in preparing for the Suitland installation was to develop a procedure that would guide the assembly of 2800 modules into 560 panels. Several outside contract manufacturers provided quotations to do this at their facilities. However, any possible savings offered by this approach were far outweighed by delivery costs from even the closest manufacturer’s location. Similarly, off-site warehouse facilities in the vicinity of the site were considered as possible assembly and staging areas. Once again, though, any cost advantage gained by having a controlled, indoor assembly facility was obliterated by the difficulties and resulting costs of transporting all 560 panels assemblies through city streets. The actual assembly work was done on-site in a tented area using specially built fixtures to facilitate the panelization. The installation crew set up equipment and materials storage, waste disposal, and an office facility on the job site. Because of the bulk of materials being processed, significant consideration was given to the flow of materials into the panelization assembly area, out into the array field, along with disposal and recycling of waste materials. A key strategy for controlling labor costs was the implementation of detailed assembly procedures, close supervision, and a continuous quality assurance program.

Once assembled, each panel had to be transported into the array field. One panel assembly of five modules weighs approximately 91 kg and is 3.35 m long and 1.22 m wide. Since they are comprised mostly of glass, it was not possible to stack these assemblies by themselves. The array field was spread out over nearly 7500 m^2, the nearest point of which was approximately one hundred meters from the assembly area, creating some unique materials handling issues. A special pallet was designed to allow four finished panels to be stacked without resting directly upon one another. The four-panel pallet could be carried by a standard four-wheel drive shooting boom construction forklift between the assembly tent and the array field. Because there was a limited number of pallets and limited storage space, a “just in time” assembly and installation process was created. Two separate teams worked in tandem; the first crew worked on fabricating panels, while the second crew was installing them on the array structure. This specialization and division of labor reduced the technical expertise required by the crews and meant that the vast majority of the panelization procedures and panel mounting procedures could be done by supervised laborers. This resulted in a significant labor cost savings over other alternatives that were considered. This approach also reduced time required for supervision of the staff, resulting in additional cost savings.

4. LESSONS LEARNED

Whenever possible, there is tremendous benefit in integrating and adapting existing trade practices into PV applications. Rather than engineering systems that require specialized skills that are unique to PV, systems should be designed to adopt existing trade practices. The best example of this approach is that of the installation of the support structure. The vertical components are 7.62 cm diameter pipes set in concrete pier foundations. The spacing, alignment, and final mechanical attachments are specialized for this photovoltaic application. The installation of these vertical supports, however, is common practice for fencing contractors. This is a practice that is easy for the fencing subcontractor to quote, source materials for, and execute. The idea is not to train, say, electricians to install photovoltaic systems. The idea is to design around existing techniques and methods that electricians and ironworkers and excavators and other tradesmen already possess and understand.

There is also a benefit to selecting materials that are already in use in other building practices. The rail material is a good example of this. The rails used for panelization are a roof framing element with the necessary structural characteristics. They were readily available and much lower in cost than custom-made aluminum rails. The manufacturer was able to punch most of the holes required for fastening the module frames. However, due in part to time constraints, a portion of the machining required for this application was done on site. Although there was a cost savings realized by using the chosen rails, those savings were diminished because some of the work necessary to complete the rails had to be done in the field. It was difficult to achieve the desired level of quality in the machining that was done on site because critical tolerances were hard to maintain with that fixtures and machines available. Had time permitted, it would have been far more cost effective to have all of the machining done at the factory. This example illustrates the cost trade off between work done in the factory and in the field, and the need to find the optimal cost balance in the face of schedule constraints.

The importance of logistics and the flow and handling of materials on a large project cannot be overstated. Thin film PV technology, in its current form, necessitates a larger number of modules and volume of balance of system components than a single crystal or polycrystalline PV array of the same peak wattage. Consequently the resolution of materials handling issues will have a large impact on the cost of construction. Even simple tasks, if done inefficiently, can have a serious impact on the cost of labor, when repeated thousands of times. In addition, repetitive inefficiencies can sap the enthusiasm and attention of the workers, which in turn carries over to general productivity, quality, and cost. Minimizing the number of steps, shortening distance between work locations, optimizing assembly procedures, and mechanizing whatever functions are appropriate, are all considerations that have a proportionally higher effect on the final cost of thin film installations and should be considered carefully during the planning stages.

The Millennia modules include several design features that facilitate assembly and installation. The Integra framed version of the Millennia modules come with factory-built mechanisms for mounting and coupling modules, making splices and routing wires. It also includes integral parallel and series conductors with plug connectors. With these features, BP Solar has gone beyond optimization of the cell properties and has engineered the product for its final field application. While this version of the module was originally designed for residential applications, we were able to adapt it for use in an industrial scale application. For this specific project, we found that the integral wiring raceways eliminated the need for additional conduit while lending a very clean appearance. We experienced difficulty with the small size of the raceways and recommend wider end channels and sleeves to protect the wires in the raceway from being damaged by mounting bolts. These criticisms aside, we believe that the philosophy of greater factory engineering for the final applications is far preferred to the more common practice of providing only a junction box and an extruded metal frame. PV modules that incorporate these sorts of mechanisms in their basic design can lead to lower design cost by the system integrator and lower installation cost by the installer.

5. SUMMARY

Thin film modules have great promise to reduce the cost of solar electricity. Increasingly, manufacturing capabilities within the PV industry are resulting in better quality products with high consistency and reliability. While the lower area efficiency can present challenges to system designers and installers, appropriate techniques can solve these issues and result in reliable, cost competitive power systems.

If the lower cost per peak Watt of thin film PV is to be realized in the final installed product, it is important that the price advantage not be lost on increased installation costs. A change in size from a smaller installation such as a two kilowatt residential system, to a larger installation, such as the 100 kilowatt, ground mounted amorphous silicon system in Suitland, Maryland, results in differences of kind and not just scale. To manage such an installation in a cost effective manner requires changes in the manufactured product, in the design and engineering of the system, and in the design and control of the installation process. The experience gained through the Suitland project proved certain techniques for managing these challenges and identified other opportunities for future improvement.

The main lessons to come out of this project were to:

- Adopt or co-opt existing trade practices whenever possible.
- Use materials that are already in use in other building technologies.
- Place particular emphasis on logistics, flow patterns and materials handling issues.
- Integrate as much of the design as possible at the (manufacturer's) factory.

As thin film PV becomes more readily available and is applied to utility-scale applications, those that are able to maximize these principles will enjoy greater success in bringing this clean energy technology to market. The 100 kW amorphous silicon PV installation in Suitland, Maryland, represents a significant step toward the day when thin film utility-scale, grid support, installations will be common.

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